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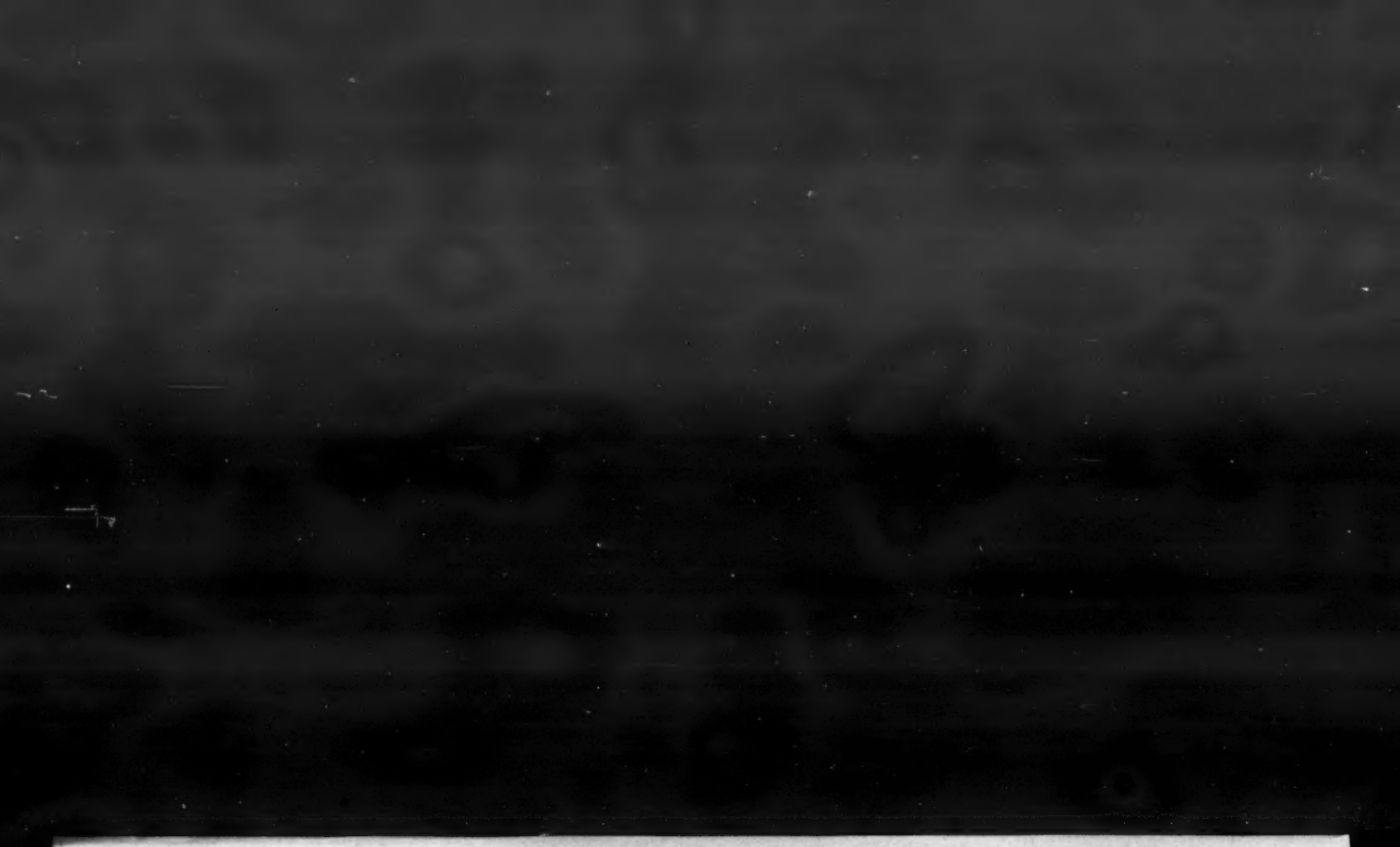

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXIII.—*Criteria relating to Massive-Solid Volcanic Eruptions;* by Israel C. Russell.

Since Monte Pelé presented geologists with a marvelous illustration of the ability of a volcano under certain special conditions to force a mighty column of solid lava vertically upward into the air from the summit of its conduit, the question has frequently been asked: Are other examples of a similar nature known? The reply is that no similar shaft of solid rock has been seen to ascend from the summit of a volcano, but evidences of former protrusions of a like nature have been recognized, and as it seems, when search is made aided by the experience recently gained on Martinique,* the records of massive-solid eruptions that have occurred in the past will perhaps be found to be somewhat common.

In order that the appearance of the example of a massive-solid volcanic eruption which will no doubt in the future be taken as the type of its class, may be fresh in mind, the reader should turn to the admirable photographs of the "obelisk" of Monte Pelé, published by Dr. E. O. Hovey, in this Journal, October, 1903.

The striking object lesson furnished by the growth of the obelisk of Pelé has already stimulated geologists to search for the records of similar occurrences in other regions. Results in this direction have been reported by Hovey,† who during a continuation of his important explorations in the Lesser Antilles, found that the Grand Soufrière of Gaudeloupe, and the prominent central peak on the Island of Saba,

* Descriptions and illustrations of the obelisk of Pelé by E. O. Hovey, have been published in this Journal, October, 1903, vol. xvi, pp. 269-281; and in Science for November 13, 1903, vol. xviii, pp. 633-634. These articles contain references to the publications of other observers. See, also, "The Pelé Obelisk," by Israel C. Russell, in Science for December 18, 1903, vol. xviii, pp. 792-795.

† This Journal, vol. xvi, October, 1903, p. 281.

bear evidence of being the result of massive-solid eruptions like that Pelé is now experiencing. "This is especially clear," writes Hovey, "in the case of the Grand Soufrière, the cone of which rises above an old crater-rim which it has buried in the same way that Monte Pelé is now striving to bury its surrounding crater-walls." The details on which this conclusion is based have not yet appeared in print, but will no doubt when published furnish a valuable contribution to the history of volcanoes.

Sir Richard Strachey, in a note in Nature,* presents a sketch, but unfortunately not accompanied by a description, of certain prominent columns in the Deccan trap region of India, which have at least a superficial resemblance to the obelisk of Pelé. The columns represented in the sketch, however, appear to be examples of the nearly complete removal by erosion of remnants of a formerly extensive lava sheet resting on less resistant beds which locally have been left in relief and now appear as buttes or hills owing to the shelter afforded by the hard bed above them. Similar buttes with prominent columns on their summits are well known in the western portion of the United States, and have long been recognized as monuments spared by erosion. This tentative explanation, while based principally on the sketch published by Strachey, and familiarity with similar topographic forms in the region drained by the Columbia River, and occupied by the Columbia River lava—the counterpart in many ways of the Deccan trap of India—is sustained by other considerations, as will appear later in this article.

Professor John C. Branner† has recently invited renewed attention to Fernando de Noronha, an island in the South Atlantic about 230 miles from the northeast coast of Brazil, the summit of which is formed by a conspicuous, irregular tower-like mass of igneous rock, 500 feet high, the inaccessible summit of which rises 1000 feet above the sea. In the article referred to mention is made of the fact that Charles Darwin, in giving an account of his observations while connected with the voyage of the *Beagle* in 1832 to 1836, remarks in reference to the Peak of Fernando de Noronha: "One is inclined to believe that it has been suddenly pushed up in a semi-fluid state." Sketches of the remarkable culminating spire of the island are also presented and its resemblance in form and similarity of position in reference to the elevation on which it stands, to the obelisk of Pelé, pointed out.

Branner states frankly, however, that the resemblance of the Peak to the obelisk of Pelé "may be quite accidental," and in the earlier article mentioned in the preceding footnote presents

* Vol. lxviii, Oct. 15, 1903, pp. 573–574.

† This Journal, December, 1903, Series IV, vol. xvi, pp. 442–444. A detailed account of the geology of Fernando de Noronha, also by Branner, was published in the same Journal, Series III, vol. xxxvii, 1889, pp. 145–161.

evidence tending to show that, as suggested by Darwin, "the Peak is part of a great dike, the only remnants of which now exposed are the upper portions of the Peak itself, and the columns at the Horta do Pico, a short distance to the south-west."

In the case of the buttes of the Deccan trap region of India, and of the Peak of Fernando de Noronha, the suggestions that have been offered in reference to their being of the same type as the obelisk of Pelé, are based almost entirely on similarity of form; but something more than this is evidently required before similarity of origin can be considered as established. In the study of topographic forms of the nature of those in question, it is essential that criteria for their classification should be formulated. An attempt in this direction will be made later in this article, after which the places to be assigned the monumental forms brought to the front by Strachey and Branner will be considered.

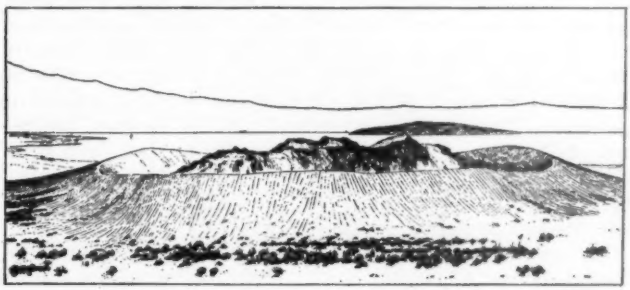

FIG. 1. Panum Crater, Mono Lake, California.
(Reproduced from the Eighth Annual Report of the U. S. Geological Survey.)

It is not necessary to go to India and Brazil, however, to find illustrations of massive-solid volcanic eruptions of the Pelé type, as instructive examples occur among the abundant volcanic records of the United States.

In the case of the extensive group of recent volcanic craters on the east side of Mono Lake, California, there are several examples of the upward protrusion of highly viscous or essentially solid lava which, in at least one instance, rose in a tower-like form to a greater height than the rim of the crater of lapilli which surrounds it. The phenomenon referred to is described as follows in my book entitled "Volcanoes of North America,"* in which the above sketch of Panum crater also appears:

* Israel C. Russell: "Volcanoes of North America." The Macmillan Company, New York, 1897, p. 221. The account of the Mono Craters presented in this book is based on an earlier publication by the same author; namely, "Quaternary History of Mono Valley, California," in the 8th Annual Report of the U. S. Geological Survey, Washington, 1889, pp. 378–386.

"In some cases when an upwelling of lava occurred [in the Mono Craters] it barely entered the bottom of the bowl of lapilli before becoming congealed. The eruption then ceased, so far as that individual vent was concerned. At other times, the thick viscid lava was forced up in the center of the crater until it stood higher than the encircling rim of lapilli, but did not expand laterally. In instances of this nature there is a deep, moat-like depression between the rough and angular protrusion of lava and the smooth inner slope of the encircling crater, in which we may walk entirely around the central tower-like mass. The type of this variety of eruption is furnished by the crater shown in the following illustration [here reproduced] which stands near the shore of Mono Lake, and has been named Panum crater."

The tower-like mass of lava in Panum Crater is not of the nature of a cone of eruption, as is explained in the monograph on Mono Valley referred to above, but a protrusion of angular, massive rhyolitic lava the chemical composition of which is given later in this essay. The lava at the time of its extrusion was so nearly solid that it rose with essentially vertical wall to a height of about 150 feet without exhibiting a tendency to flow in any direction. In the light of the recent example furnished by Pelé, this protrusion of lava may be accepted as being of the nature of a massive-solid eruption, which occurred subsequent to the explosive eruptions that built the sharp-crested encircling crater of lapilli.

The observations pertaining to a peculiar volcanic eruption which occurred in Bering Sea in 1883, during which the shape of Bogosloff Island was greatly altered, are discussed in "Volcanoes of North America," referred to above, and the following conclusion as to its general nature presented:

"Although not personally familiar with Bogosloff, I venture to suggest, from what I have seen in connection with other volcanoes, that the formation of the island was due to the outwelling of viscous lava, which hardened at the surfaces so as to resemble the rough, scoriaceous surfaces so common in lava flows. The lava, being quickly cooled, did not flow as a stream, but as in the case of some of the Mono craters previously described, rose in rugged scoriaceous masses, without much explosive violence. Nothing resembling a crater ring of lapilli and dust is reported as surrounding the elevated crags of lava."

Here again the evidence, interpreted with the aid of the more typical example furnished by Pelé, indicates that a massive-solid eruption occurred. In this instance, the volcanic conduit opened beneath the sea, and the eruption was subaqueous, but a protrusion of essentially solid lava took place, the summit of which rose to a height of 325 feet above the

ocean's surface, and, as is shown by a sketch* made in the fall of 1883, here reproduced, had a tower-like form similar to the obelisk of Pelé.

The rock of which Bogosloff is composed, as determined by G. P. Merrill,† is hornblende-andesite, an analysis of which is presented in the table on page 261 of this essay.

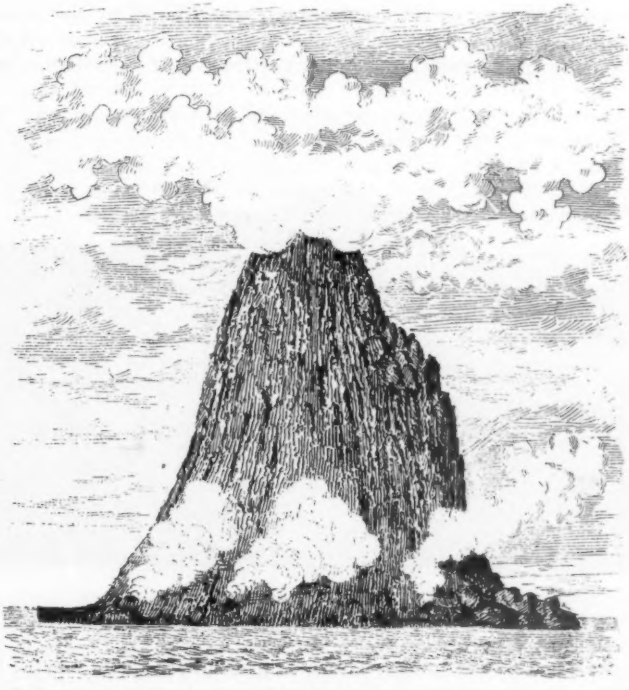

FIG. 2. The New Volcanic Island of Bogosloff, as seen September-October, 1883. After W. H. Dall.

In the case of Bogosloff, there is no evidence on record of a lava flow, or that any of the material extruded was in a fluid or even moderately plastic condition. As will be remembered, no fluid lava was discharged from Panum Crater, and up to the present time during the still continuing period of activity of Pelé only fragmental-solid and massive-solid eruptions have occurred, excepting that highly viscous clots which fell as

* Science, vol. iii, 1884, p. 285.

† Science, vol. iv, 1884, p. 524; also Rocks, Rock-Weathering and Soils, by the same author. The Macmillan Company, New York, 1897, p. 84.

"bread-crust bombs" were thrown out. It is of interest to add to this short list of volcanoes which have erupted material in a massive-solid condition, another example, from which lava was discharged in the three or four ways illustrated by Pelé, and also gave origin to a stream of lava.

The volcano referred to is one of five of modern date (post-Glacial) situated on the east border of Pauline Lake in the south-central part of Oregon, which was visited by the writer during the summer of 1902. A view of the interior of the crater, showing a rough but generally level surface surrounding

FIG. 3. Crater of a volcano near Pauline Lake, Oregon, with massive-solid extrusion in its center.

a central mass of crags, is here presented. The rim of the crater, not appearing in the illustration, is composed mainly of light-colored pumiceous lapilli, and is still intact for about three-fourths of its original circumference, but its northern portion is concealed, or more probably was breached and carried away by a lava flow which was discharged from the crater and went northward for a distance of two miles, and expanded to a width of about one mile. All of the material extruded seems to be andesite, which ranges in physical characteristics from compact, dense, black volcanic glass or obsidian, to yellowish-white pumice so light that it will float on water with the buoyancy of cork. The lava stream has an excessively rough surface, consisting of blocks of obsidian of all sizes up to eight or ten or more feet in diameter with sharp edges and corners, which form irregular piles and ridges in many instances fifty

or more feet high, as well as massive escarpments and smooth fissure-walls of the same material. In many places the glass passes into a highly scoriaceous rock, resembling a coarse black pumice. Along the sides and at the distal end of the lava stream it terminates in precipitous escarpments, exceedingly difficult to climb, from 50 to 80 feet high. The slope down which the lava flowed has a descent by estimate of at least 500 feet to a mile, and the fact that the stream halted on such an incline and cooled with essentially vertical borders, shows that it was excessively viscous at the time it was spread out.

The feature of chief interest in connection with the volcano in question is a tower-like mass of crags of gray stony or granular homogeneous augite-andesite (as determined by F. C. Calkins, of the U. S. Geological Survey), without either obsidian or scoria and in which there is a notable absence of a "flow-structure," which rises to a height of about 250 feet above the crater's floor. The sides of the central mass of crags, as may be judged from the accompanying photograph, are precipitous, and allowing for the blocks that have fallen, must at one time have been nearly vertical. The lava of which the crags are composed is fresh in appearance, there being no discoloration of the surface, and scarcely a lichen has taken root upon it. It exhibits no evidence of there having been a tendency to flow laterally at the time it was upraised, and although irregularly jointed is not columnar.

A peculiar feature of the floor of the crater at the base of the crags described above is that the lapilli, of which it is composed, are in irregular heaps and piles with steep-sided depressions between, the variations in height between the hills and hollows being from 10 to fully 30 feet. The topography of this surface is surprisingly like that of certain glacial moraines, but its roughness is due in part to the occurrence, at a late stage in the activity of the volcano, of many mild steam explosions in the fragmental material of which it is superficially composed, and in part to the formation of fissures in the rocks beneath, which permitted the loose material resting on them to subside irregularly. About the outer margin of the floor of the crater from its eastern around its southern to its northwest portion, there is a belt about 150 feet wide composed of obsidian and black scoria, which resembles the surface of the associated lava flow. This partially encircling belt of large fragments margining the crater's bottom is due to motion which took place after the lava of which it is composed became solid, but whether the motion was of the nature of an underflow in still viscous material beneath a rigid crust, or was an upward movement of the entire lava column within the crater, is uncertain. I am inclined, however, to the latter opinion.

Without attempting to put on record at this time all of the instructive features of the volcano on the border of Pauline Lake, the facts in its history of chief interest in connection with the study of massive-solid eruptions may be briefly enumerated as follows:

The beginning of the eruption was characterized by the occurrence of violent steam explosions, which blew away the highly scoriaceous summit portion of the column of molten material that rose in the conduit of the volcano; the material thus extruded consists mostly of light colored pumice, but mingled with it are sharp-edged flakes of obsidian, and fell about the opening from which it came so as to build a well defined, sharp-crested crater with smooth slopes. The product of these earlier explosions, together with the similar material blown out at about the same time from four associated volcanoes of the same character, was distributed widely over the adjacent mountains. Succeeding the earlier and most violent explosions, came an outwelling of viscous lava which flowed northward down a moderately steep incline, but did not spread widely and was so thick and viscous that it came to rest with nearly vertical borders, the slopes of which have since been reduced by the shattering of the glass of which they are composed, and the fall of the fragments so as to make steep talus aprons. After the discharge of viscous lava, the central portion of the ascending lava column became rigid and was forced upward by pressure from below until it stood, as at present, in massive crags, 250 feet high. Changes of temperature have caused some shattering of the central mass of stony andesite, but not nearly so much as in the case of the surface of the neighboring obsidian lava-flow. Following or accompanying the protrusion of the central crags, renewed but minor explosions occurred about its base, during which the rocks involved were broken and tossed about but not thrown to a great height or widely distributed. Mingled with the angular fragments now occupying the larger portion of the crater and filling it nearly to the level of the part of its encircling rim which remains, there is an occasional volcanic bomb. These bombs have something of the characteristic football shape common among such volcanic products. The examples seen are about eight inches in diameter, and do not show a "bread-crust" or other conspicuous surface features. These masses were projected into the air during explosions in a viscous condition, and received their rudely spherical shapes owing to rotation about their longer axes during their ærial flights. They cooled before striking the ground and were not flattened, and were not sufficiently plastic to adhere to the loose stones on which they fell. Following the period of mild,

superficial explosions came movements which broke the rocks on which rests the irregular surface covering within the crater, and apparently an ascent through a distance of a few feet of nearly its entire mass.

The short list given on the preceding pages, namely, certain of the Mono Craters, Bogosloff, and the nameless crater in Oregon just described, contains all the known or reasonably inferred examples of massive-solid volcanic eruptions in America, which can be referred to the Pelé type.

With the fresh impetus to the study of volcanoes supplied by the remarkable behavior of Pelé, a demand has been made manifest for criteria by means of which the topographic forms produced by massive-solid eruptions can be distinguished from analogous features in the relief of the land. The first step in this direction is the formulation from all available data, aided by reasonable inferences, of a mental conception of the topographic and other characteristics that massive-solid eruptions should present. The facts in hand are sufficient to enable one to make an approximation to such a conception, but the picture will no doubt have to be modified as investigation progresses.

TABLE OF ANALYSES.

Constituents.	No. 1. Rhyolite.* Mono Lake.	No. 2. Hypersthene† Andesite. Monte Pelé.	No. 3. Hornblende Andesite.‡ Bogosloff.	No. 4. Phonolite.§	No. 5. Basalt. Cinder Buttes. ‖
SiO_2	74·05%	61·44%	56·07%	58·02%	51·14%
Al_2O_3	13·85	17·27	19·06	20·03	13·95
Fe_2O_3	trace	2·53	5·39	6·18	2·15
FeO		4·18	0·92		12·97
MgO	0·07	2·28	2·12	0·80	2·21
CaO	0·90	6·36	7·70	1·89	6·56
Na_2O	4·60	3·54	4·52	6·35	3·59
K_2O	4·31	1·49	1·24	6·18	2·33
H_2O	2·20	·88	0·99	1·88	·34

* Analysis by T. M. Chatard, U. S. Geological Survey, 8th Annual Report, 1886–87, Pt. I, p. 380.

† Analysis by W. F. Hillebrand, National Geographic Magazine, vol. xiii, July, 1902, p. 291; average of three analyses; minor ingredients as given in original report are not included.

‡ G. P. Merrill, Rocks, Rock-Weathering and Soils, p. 84.

§ G. P. Merrill, Rocks, Rock-Weathering and Soils, p. 80. Average of six analyses given by Zirkel; includes also MnO, 0·58 per cent.

‖ Analysis by W. F. Hillebrand, U. S. Geological Survey, Bull. 199, p. 87: contains also TiO_2 2·41 per cent; ZiO_2 0·12 per cent; MnO 0·44 per cent; BaO 0·25 per cent; P_2O_5 1·59 per cent; Fl 0·10 per cent; FeS_2 (S = 0·08) 0·15 per cent, and traces of V_2O_3; NiO; SrO; and Cl.

One of the first questions to present itself in searching for criteria by means of which massive-solid can be distinguished from other volcanic eruptions, is: Do the lavas extruded in

that condition have any characteristics in their chemical composition which will serve to differentiate them from other lavas? The reply, so far as it can at present be formulated, must evidently be based on the analyses of the rocks known to have been extruded in a massive-solid condition and a comparison of them with the composition of lavas not known to have been erupted in that manner.

In the above table the available analyses of the examples of massive-solid eruptions described on the preceding pages, have been assembled, together with an analysis of a characteristic phonolite (No. 4) to represent the rock of the Peak of Fernando de Noronha, and also an analysis of basalt (No. 5) which is known to have been erupted in a highly fluid condition.

To the examples of massive-solid eruptions cited in the table, should be added an analysis of the augite-andesite of the crater near Pauline Lake, Oregon, described on a previous page, but this data is not available.

As indicated by laboratory experiments made on the fusibility of shales and clays* similar in chemical composition to the rocks enumerated above, the relative fusing points of such rocks may be roughly or qualitatively expressed by the ratio of the silica and alumina to the iron oxides, magnesia, lime, soda and potash, or the "fluxes" present in them. The rule being that for mixtures of the general nature that lavas present, the higher the ratio of the silica and alumina to the fluxes present, the greater the degree of heat necessary to cause fusion, under laboratory conditions. On arranging the analyses given in the above table, so as to indicate the ratio of acid to basic substances given, we have the following:†

TABLE SHOWING RELATIVE FUSIBILITY.

	$SiO_2 + Al_2O_3$.	"Fluxes."	Ratio of $SiO_2 + Al_2O_3$ to "Fluxes."	Approximate temperature of fusion.‡
1. Rhyolite of Mono Craters	87·90%	9·88%	8·8	3100°F.
2. Andesite of Pelé	78·71	19·88	3·9	
3. Phonolite	78·05	21·40	3·6	2520
4. Andesite of Bogosloff	75·13	21·89	3·4	
5. Basalt of Cinder Buttes	65·09	29·81	2·2	2250

As indicated by the ratios given in the third column of

* H. Ries, Clays and Shales of Michigan, in Geological Survey of Michigan, vol. viii, Part I, 1900.

† This table is only approximately correct since no account is taken of the water present; and in the case of the numbers 2 and 5, no account is taken of the several minor constituents given in the analyses as originally reported.

‡ According to experiments by C. Barus, quoted in J. D. Dana's Manual of Geology, 4th ed. 1895, p. 273.

the table, the rocks are arranged according to their degree of fusibility; the most refractory being the rhyolite, and the most fusible the basalt. The known massive-solid eruptions 1, 2 and 3 are thus shown to consist of refractory lavas. On the other hand, basalt, which so far as known has not been extruded in a massive-solid condition, is more readily fusible, and in the case of the example cited, as recorded elsewhere,* was poured out in a highly fluid condition. From the data in hand it appears, therefore, that one of the characteristics of the rocks known to occur in massive-solid extrusions is their refractory nature. That this is always a characteristic condition, however, cannot as yet be definitely affirmed. Another related condition is the amount of water-vapor present, since aqueo-igneous fusion is known to require much less heat than dry fusion. The bearing of this principle on the occurrence of massive-solid volcanic eruptions, although seemingly of fundamental importance, cannot be discussed at this time. Assuming, however, that the influence of water-vapor on the fusion of acid and basic lavas is the same, it is evident, from the data given above, that the former should occur more commonly than the latter, in massive-solid extrusions.

In addition to the presence of a plug of rigid lava in the summit portion of a volcanic conduit, in order to bring about a massive-solid extrusion, it is evident that there must also be sufficient pressure on the base of the plug to force it out. Such pressure, as we know, is present during the eruptions of many and we presume all volcanoes which discharge lava. The critical or determining conditions, which lead to massive-solid eruptions, seem to be that the lava in the summit portion of a volcano in action shall become solid. The lavas most apt to solidify at such times are evidently those which are refractory and on cooling pass quickly from a fluid to a rigid condition; that is, the lavas rich in silica and alumina and relatively poor in basic substances. Hence as it seems, it is to be expected that massive-solid extrusions will consist of rocks like the rhyolites, trachytes, andesites and phonolites, rather than basalts or still more basic lavas.

Judging from the heated conditions of the material extruded during a massive-solid eruption at the time it rises into the air, and reasoning also from the known variations in the physical and mineralogical features of igneous rocks which depend on the conditions under which they solidify, we should expect the lavas extruded in a massive-solid condition to present at least three leading physical characteristics: they should be (1) compact, or at most but moderately vesicular, and not scoriaceous, (2) granular or perhaps finely crystalline but not glassy, and

* Israel C. Russell, U. S. Geological Survey. Bulletin No. 199, Washington, 1902, p. 88.

without conspicuous crystals, and (3) irregularly jointed but without a well defined columnar-structure. Each of these propositions may for convenience be considered separately:

1. A compact rather than a scoriaceous condition of the lava forced out during massive-solid eruptions is to be expected from the fact that preceding liquid or fragmental-solid discharges would have removed the more thoroughly vapor-charged summit portion of the rising column, while the material at a greater depth, less thoroughly vapor-charged and congealing under pressure, would form a compact lava. Turning to the known examples of massive-solid eruptions available for comparison, we find this conclusion sustained in the case of the central crags in the Oregon crater described above, which consists of compact granular material.

2. A stony or granular texture, without well defined or conspicuous crystals, would be expected because the lava consolidates with comparative rapidity near the summit of the conduit from which it is later extruded, thus not allowing sufficient time for an advanced stage of crystallization. On the other hand, cooling takes place less rapidly than in the surface portion of a lava sheet, and a glassy texture would not be expected. The rock in question should seemingly be intermediate in structure between those which cool slowly, as in intruded sheets and the central parts of thick lava flows, and those which cool so rapidly that a glass (obsidian) results. Although this reasoning seems to be logical, yet, as is well known, crystals are sometimes formed in deep-seated magmas and are carried to the surface when the containing magmas migrate outward and are discharged by volcanoes. This phase of the problem is obscure, and possibly a granular or crypto-crystalline structure may not be an essential characteristic of lava extruded in a massive-solid condition.

Turning again to the known examples, we find the rock composing the crags in Panum crater, and the one in Oregon described above, to be stony in texture, and in the case of the Oregon crater at least, without either porphyritic crystals on the one hand, or obsidian or pumice on the other.

3. Columnar structure in igneous rocks, as is well known, results from slow cooling, and the columns formed under such conditions have their longer axes at right angles to the cooling surfaces. As the material forced out during massive-solid eruptions is still hot when it reaches the air, and as the diameter of such extruded masses, so far as known, is but a few hundred feet, it is to be expected that cooling would progress too rapidly and too irregularly to permit of the formation of systematically arranged joints, and hence, a well-defined columnar structure would be absent. If in large extrusions the rate of cooling did permit of the origin of a columnar structure, the columns

should be best defined in the central part of the mass, and radiate outward from a central vertical axis toward the sides. The most that could seemingly be expected, however, would be irregular and confused jointing without the formation of a columnar structure. Once more checking deductions by observation, we find no evidence of columnar structure in the massive-solid material extruded from either the Panum crater or the crater near Pauline Lake. As to the other examples cited, information in this connection is lacking.

There is one other feature of volcanic rocks which might reasonably be expected to occur in those forced to the surface in a massive-solid condition, namely, a brecciated structure; that is, the presence of angular fragments of the parent lava, adhering one to another or united by portions of the same magma which consolidated about the fragments produced by the fracturing of the portion which cooled earlier. Such volcanic breccias are common in the lava flow about the Mono craters, and in the similar lava stream near Pauline Lake, but have not been observed in the massive-solid extrusion of those localities. From the manner in which massive-solid eruptions take place, however, it seems as if the conditions would favor the production of brecciated rock of the type just mentioned.

The crucial test of the above deductions will come when the activity of Pelé has decreased sufficiently to permit of a critical study of its obelisk. The prediction may be ventured, however, that it will be found to be composed of massive but somewhat porphyritic rock since the products of the fragmental-solid eruption are of this nature, and without definite columnar structure, although irregular or confused jointing will no doubt be present.

In reference to the topographic forms analogous to those produced by massive-solid eruptions and which might be mistaken for them, there are seemingly but three directions in which uncertainty is likely to arise. These are: (1) the similarity in shape and in location of the crags, spines, obelisks, etc. produced by massive-solid eruptions, and the ordinary *cones of eruption* such as are typically illustrated by the one which forms from time to time within the crater of Vesuvius; (2) the similarity of obelisks, etc. to the tower-like forms produced by the erosion of craters within the conduits of which lava has cooled and hardened, so as to form what are termed *volcanic necks;* and (3) the tower-like forms resulting from the weathering of lava sheets which rest on less resistant and as is most commonly the case, incoherent sedimentary strata, or beds of tuff, and frequently termed *erosion columns*.

1. The necessity of distinguishing between massive-solid eruptions and cones of eruption arises principally from the fact that in fresh and well-characterized examples of each class, an elevation is present within an encircling crater. Cones of erup-

tion, however, in all known instances are composed of highly scoriaceous material, consisting of lava blocks, lapilli, bombs, cakes formed of splashes of liquid lava, dust, etc., and have a tube or conduit within, leading upward to a crater at the top. Such structures are in fact miniature volcanic cones of the same general character as the greater cones in the craters of which they are formed. In all of the characteristics mentioned the differences between cones of eruption and massive-solid extrusions are obvious and need no further discussion.

2. The similarity between volcanic necks exposed by the removal of their enclosing cones, and the tower-like forms produced by massive-solid extrusion, as in the case of Pelé, is most striking. This similarity approximates to identity, inasmuch as a volcanic neck and a volcanic obelisk may be portions of the same lava column; the former being the material within a conduit which cooled in place, or if forced upward did not emerge from its enclosing tube, while the latter represents the summit portion of a congealed lava column that has been forced out of its parent conduit.

Fresh and uneroded obelisks are not to be mistaken for volcanic necks exposed by erosion, because of their freshness and the presence about them of crater walls, or evidence of the destruction of such encircling rims by explosions, or their burial beneath the debris falling from the obelisks themselves, etc. It is in drawing distinctions between much weathered obelisks and volcanic necks when exposed by erosion, that difficulty is likely to arise.

In the case of well-characterized volcanic necks and good although much weathered examples of volcanic obelisks, it seems possible to draw a distinction, although their shapes, positions, etc., are essentially the same. The material forming a volcanic neck cools slowly on account of the insulation afforded by its enclosing cone, and would be expected to form a well crystallized and, in the case of most lavas, a porphyritic rock. Owing to slow cooling, also, the rocks of volcanic necks should exhibit a well defined columnar structure. Such we know to be the case in certain typical examples situated in the northwestern part of New Mexico and having a height of from 800 to 1000 feet above the adjacent plain, concerning which Major C. E. Dutton* writes as follows: "In all of these necks the basalt is columnar. The columns stand or lie in all sorts of attitudes, and in most cases are curved. Frequently they are grouped in radiating *fasciæ*, and at times are flexed and reflexed." The columns are described as varying in size from five or six inches to more than twenty feet across; the larger ones being generally vertical.

* Mount Taylor and the Zuñi Plateau, in Sixth Annual Report of the U. S. Geological Survey, Washington, 1886, p. 172.

Then, too, volcanic necks may contain rocks of any chemical composition ranging from ultra-basic to ultra-acid, that are extruded by volcanoes; while, as already stated, there seem to be good reasons for concluding that massive-solid eruptions occur only in the case of volcanoes which are supplied with highly refractory lavas.

With these considerations in mind, any monumental rock that simulates an obelisk in form, which is composed of basic or, more strictly, easily fusible material, might with greater probability be classed as a volcanic neck, then as a volcanic obelisk. And again, if the material composing such a monument is coarsely crystalline, and traversed by definite systems of joints, producing a well-defined columnar structure, the evidence is seemingly conclusive that it is not of the nature of a volcanic obelisk. In this connection the conditions revealed by the uncovering and erosion of subterranean intrusions, such as dikes, plutonic plugs, laccoliths, etc., need to be borne in mind, but space does not permit of considering them at this time.

Reverting to the case presented by Fernando de Noronha; the topographic form and prominent position of the Peak are such as to simulate in a remarkable way the conditions that may reasonably be supposed to pertain to a weathered obelisk; the rock of which it is composed, as reported by Darwin and Branner, is phonolite, and although, so far as I am aware, no analysis is available of this particular example, phonolites in general have approximately the composition indicated in the table presented above, and are to be included among the igneous rocks of medium fusibility. The rocks associated with the phonolite which forms the Peak of Fernando de Noronha and other neighboring elevations, as stated by Branner,* are of a basaltic type and compose the greater part of the island. From this same authority also, we learn that the phonolite of the Peak is conspicuously columnar; "The direction of the columns varies in some cases as much as fifty degrees. The lowest rocks of the Peak exposed in place are the irregular columns upon the eastern side. The columns are here very nearly vertical; but higher up, even upon this side, they twist and bend to the northeast and thus form the overhanging projection which is so remarkable a feature of this great rock. . . . . On its western side the columns stand at various angles with the meridian, and usually at a high angle with the horizon." A comparison of this description with that of the columnar structure of the volcanic necks of New Mexico, quoted above, is highly suggestive.

It thus appears that the facts recorded concerning the Peak of Fernando de Noronha do not furnish positive evidence as to its mode of origin. Its shape and prominent topographic position are similar to those of the obelisk of Pelé, but on the

* This Journal, III, vol. xxxvii, 1889, p. 150.

other hand, correspond fully as well with the similar features of many volcanic necks. The chemical composition of the rock of which the Peak is composed, so far as suggestive of its degree of fusibility, is similar to that of the material erupted by Pelé; and so far as this fact has weight, it is evidently not opposed to the idea that the rock in question was extruded in a massive-solid condition. The well-defined columnar structure of the Peak, however, is so similar to that of many volcanic necks and still more numerous igneous dikes, and is so unlike the jointing observed in at least two examples of massive-solid extrusions, and so unlike, also, as we seem justified in assuming, the jointing to be expected in all such extrusions, that it favors the conclusion of its being a volcanic neck or a portion of an igneous dike, rather than of the nature of the obelisk of Pelé.

In reference to the criteria by means of which a distinction can be drawn between residual masses of lava sheets left as columns on the tops of hills or buttes, and obelisks of the Pelé type, but little need be said, since even a cursory examination of such monuments of erosion is usually sufficient to reveal their history. Erosion columns may be composed of any variety of volcanic rock, but as is well known, are most commonly basaltic, are usually vertically jointed and frequently conspicuously columnar, and rest on soft or incoherent material. In most instances, also, in regions where one such residual column occurs, others of similar nature are apt to be present, as well as flat-topped mesas and even broad table-lands. Thus in the nature of the material of which the columns referred to are composed, and in their structure and associations, they differ widely from massive-solid extrusions.

It is at present impracticable to apply the above mentioned criteria to the columns in the Deccan trap regions of India, referred to by Strachey, except so far as topography and the general nature of the rock are concerned. Topographically the columns represented in the sketch mentioned on an early page of this essay, seem to agree much more nearly with erosion columns than with volcanic obelisks, a view which is sustained by the presence of two examples near each other. The Deccan trap is composed of basaltic rock, such as is common in erosion columns and not as yet known to occur in volcanic obelisks. The evidence seems, therefore, to indicate that the columns in question are residual masses left by the nearly complete erosion of a formerly widely extended sheet of lava.

From the considerations presented in this essay, it will be seen that the recent eruptions on Martinique have made important contributions to both geology and geography. In the investigation of volcanoes geological and topographical studies go hand in hand and mutually assist each other.

Art. XXIV.—*On a New Nepheline Rock from the Province of Ontario, Canada;* by Frank D. Adams.

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In a paper which appeared in this Journal some years since,* the discovery of a large body of nepheline syenite in the township of Dungannon, in eastern Ontario about 85 miles northwest of Kingston, was recorded. As stated at the time, this occurrence is of large dimensions and the rock constituting it is in many respects remarkable in character. The discovery was one of the first results of a geological survey of this part of Ontario—at that time, geologically speaking, a *terra incognita*—which had just been undertaken by the writer for the Geological Survey of Canada. As the survey was continued during several succeeding summers, many additional occurrences of nepheline syenite were discovered and mapped, and as the result of more extended study the area is now known to present one of the most extensive and interesting developments of nepheline-bearing rocks which are known to occur anywhere. The geological maps of the area in question, by Dr. Barlow and the writer, are now completed and are being engraved, and it is expected that they, with the accompanying report, will be ready for distribution shortly. During the progress of the survey, Prof. Miller and Dr. Coleman of the Ontario Bureau of Mines visited the district and described certain of the occurrences of the nepheline syenite in papers published in the Reports of the Bureau and elsewhere.

When engaged in elaborating their Quantitative System for the Classification of Igneous Rocks, Messrs. Iddings, Cross, Pirsson, and Washington found that certain subdivisions of their scheme had no representatives amongst the rocks hitherto described. One of these subdivisions was Order 8 of the Peralkalic Persalanes, to which would belong nepheline syenites very poor in feldspar and very rich in nepheline, with perhaps allied varieties of related rocks. As it has been mentioned in the paper on the Dungannon nepheline syenite, that in that district rocks composed almost exclusively of nepheline occurred, the authors of the Quantitative Classification suggested that this order might be called Ontarare. No analysis, however, of any of these rocks had then been made, so that their precise composition remained somewhat doubtful. The name Ontarare, however, was given to the order, the present writer undertaking to make good the claim of the Province to the bestowal of the name, by describing an Ontarare from the district in

* F. D. Adams: On the Occurrence of a Large Area of Nepheline Syenite in the Township of Dungannon, Ontario, this Journal, July, 1894.

question which would serve as a type for the order. It is the purpose of the present paper to make good this undertaking by describing the first Ontarare.

The nepheline syenites of eastern Ontario, while always presenting the same general character, are represented by many varieties. The rock is usually coarse in texture, while in some of its pegmatitic developments the most extraordinary size of grain is attained. In one occurrence near the village of Gooderham in the township of Glamorgan, consisting of nepheline, albite, and an occasional individual of lepidomelane, the nepheline masses—for the most part single individuals—are often as much as three feet in diameter; while in several other occurrences nepheline syenite pegmatites of almost equal coarseness of grain have been found. The rock, furthermore, differs from that of most nepheline syenite occurrences, in that it commonly presents a more or less distinct foliation or gneissic structure, which foliation is not due to crushing *in situ* with the development of cataclastic structure, but is produced by a parallel arrangement of the constituent minerals, which arrangement seems to be a primary one or is at least unaccompanied by pressure phenomena.

The nepheline syenites of the region, furthermore, show a wide variation in mineralogical composition, several varieties often occurring together in the same mass, forming rude bands which coincide in direction with the foliation, thus serving to accentuate this and render it more pronounced.

The iron-magnesia constituent which is most commonly present is hornblende, represented by alkali-rich varieties, of which hastingsite may be taken as a type.* Pyroxene, however, replaces this in some cases and biotite in others. In some places these minerals preponderate over the colorless constituents of the rock and in these varieties garnet locally occurs in considerable amount. These dark bands, or schlieren, are, however, not very common and the prevailing facies of the rock is one which is light in color owing to the abundance of feldspar and nepheline. In certain occurrences other minerals which usually play the part of accessory constituents—such as corundum, sodalite, and cancrinite—attain more prominence, the first mentioned mineral now being very extensively mined in an occurrence of the syenite, near Combermere; while some of the largest masses of sodalite† which have ever been found are those which have been obtained from the nepheline syenite in

* F. D. Adams and B. J. Harrington: On a New Alkali Hornblende and a Titaniferous Andradite from the Nepheline Syenite of Dungannon, Ontario, this Journal, March, 1896.

† B. J. Harrington: On Nepheline, Sodalite and Orthoclase from the Nepheline Syenites of Dungannon, Hastings Co., Ontario, this Journal, July, 1894.

the township of Dungannon, to the east of the village of Bancroft.

These nepheline syenites occur cutting the rocks of the Grenville series, which consist largely in this district of crystalline limestones. Their wall rock consequently in almost every case is limestone. The only occurrence which is not directly associated with large masses of this rock is a large isolated intrusion in the township of Methuen, where the country rock is granite and amphibolite, the latter holding only a few small limestone bands.

With this is connected one of the most curious phenomena presented by these nepheline syenites, namely, the presence in them almost everywhere of calcite. This calcite when appearing in the analysis of a rock at once suggests an advanced stage of alteration, since calcite when found in igneous rocks is almost invariably a secondary product. In other cases calcite in plutonic rocks has been supposed to occupy miarolitic druses and to have been deposited in these by percolating waters.

A very careful examination, however, of the calcite-bearing occurrences of nepheline syenite in the various parts of this area has clearly shown that in the case of these rocks the calcite represents inclusions of the crystalline limestone penetrated by the intrusion, a fact which receives additional substantiation in the fact that in the Methuen occurrence, when the wall rock is not limestone, the nepheline syenite does not contain calcite. Along the borders of the intrusion, the nepheline syenite is seen to eat into the limestone and to enclose large masses, the constituent minerals of the syenite growing into the substance of the limestone, often with well defined crystal terminations. These masses often show a coarsening in grain as a result of the metamorphic action of the intruding rock. On receding from the contact, the inclusions become less numerous and smaller, and eventually the large masses are disintegrated into separate individuals of calcite or small groups of calcite grains. These, under the microscope, can be seen as rounded, often perfectly round, inclusions completely enclosed in a single individual of nepheline or other constituent of the nepheline syenite, or lying between other constituents of the rock, which latter can be seen to have grown into the calcite. In these cases all the minerals are perfectly fresh and unaltered, and, while the constituent minerals of the nepheline syenite rarely show pressure phenomena, the calcite individuals are often seen to be much bent and twisted and to display marked strain shadows, the movements displayed being those which overtook the limestone before the intrusion of the syenite into it.

It being, therefore, clearly recognized that the calcite is some-

thing foreign to the original magma and that it merely exists in the rock in the form of inclusions, in calculating out the mineral composition of the rock the calcite is set aside and the primary magma regarded as having the composition of the calcite-free rock. The nepheline syenite of the island of Alnö,* it may be mentioned, is characterized by the presence of calcite which is not of secondary origin, whose mode of occurrence in many respects is very similar to that of the calcite found in the nepheline syenite of Ontario.

Seven typical varieties of the rock have been analyzed and these serve to show the range in composition displayed by the magma. Of these, three were found to belong to the class of the Persalanes and to the sub-class Pesalone; using the nomenclature recently proposed by Messrs. Cross, Iddings, Pirsson and Washington,† while three others belong to the class Dosalane and the sub-class Dosalone. One is a Phlegrose, one a Vulturose and one a Miaskose, while two are referable to Essexose and one is a Kallerudose. These will be fully described in the forthcoming Report to which reference has already been made.

In addition to these there is the rock described in the present paper. This is a variety of the nepheline syenite which is almost free from feldspar and which consists essentially of nepheline and the iron-magnesia constituent, in this case hornblende. It occurs in the township of Monmouth, about 25 miles west of the township of Dungannon. Here, on lots 9, 10, 11 and 12 of ranges VII to VIII, a mass of nepheline syenite breaks up through a great band of crystalline limestone. The southern limit of this mass is unfortunately mantled by drift, so that its extension in this direction is somewhat uncertain. It has, however, the form of a flattened ellipse, the longer diameter measuring one mile and the shorter diameter about half a mile, and is completely surrounded by the limestone. The mass holds many inclusions of the limestone through whose shattered mass it penetrates. These included limestones frequently are coarsely crystalline and are more or less impure from the presence of secondary silicates developed by the contact action. These masses have the appearance of being in process of replacement by the intruded magma. The nepheline syenite in some places along its contact with the limestone is rich in hornblende, but elsewhere along the border it contains but a very small proportion of the dark constituent, so that no distinct endomorphic action can be traced to the influence of limestone. In some few places, however, near the limestone

* Hogbom, A. G.: Ueber das Nephelinsyenitgebiet auf der Insel Alno. Geol. Fören. i. Stockholm Förh., Häft. 2, 1895, p. 140.

† Quantitative Classification of Igneous Rocks, University of Chicago Press, Chicago, 1903.

the syenite holds scapolite. Taking the intrusion as a whole it may be said to consist essentially of albite, nepheline and hornblende, but as is so frequently the case in this region it shows a wide variation in relative proportion of the constituents in different places. In some places it is rich in feldspar, while elsewhere the nepheline almost entirely replaces this mineral. In the latter case the nepheline is usually associated with a considerable amount of hornblende, in addition to which in many cases a small amount of red garnet is present.

The feldspathic and feldspar-free varieties run in rudely parallel bands or schlieren. These are often several feet in width and may be traced for several hundred yards along the strike of the banding. They represent distinct magmas resulting from extreme differentiation. The rock here described was collected from one of the bands six feet in width and several hundred yards long.

The rock is coarse in grain and consists essentially of white nepheline and black hornblende, the former preponderating largely. It thus has a rather striking appearance on the fresh fracture. On the weathered surface the contrast presented by the two minerals is less striking, as the nepheline assumes a pale gray color. Under the influence of the weather, the nepheline, as is always the case with these rocks in this district, presents the appearance of having been dissolved away, the weathered surface being smooth and recessed, the hornblende and the accessory feldspar and cancrinite of the rock standing out from the surface of the nepheline.

Under the microscope the rock is seen to consist essentially of nepheline and hornblende, with plagioclase, cancrinite, and calcite as accessory constituents, as well as sodalite, apatite, sphene, biotite, pyrite and iron ores, these latter minerals being present in extremely small amounts.

The Nepheline occurs in large well-defined grains, presenting the usual characters displayed by the species. It is clear and fresh.

The Hornblende is green in color, the pleochroism and absorption being as follows: a= pale greenish yellow. b and c= very deep green. The absorption is $c=b>a$. The maximum extinction observed in the sections of the rock was 19°. It is an alkali hornblende, containing less iron than hastingsite, but, like it, as shown by the calculation of the analysis of the rock, belonging to the division of the Syntagmatites.

The Plagioclase is present only in very small amount and is in some cases untwinned, while in other cases it shows a faint, polysynthetic twinning. In thin sections it bears a very close resemblance to the nepheline, and when untwinned it is difficult in all cases to distinguish the two minerals. When a sec-

tion is treated with acid and etched, however, the plagioclase is seen to occur in individuals of a more or less rounded form or with curving outlines, lying between the nepheline grains or enclosed in the latter. The feldspar isolated from another variety of the rock in the same occurrence was found to be albite, and this feldspar has, therefore, been taken as albite in calculating the Mode of the rock.

The amount of Cancrinite present varies very considerably in different specimens of the rock. In the specimen analyzed about 5 per cent was found. In other specimens more is found, although in no case is it very abundant. It is clear and colorless, but is at once distinguished from the nepheline when examined between crossed nicols by its much higher polarization colors, which in thin sections frequently rise to a blue of the second order. It is clear and free from interpositions and in convergent light is seen to be uniaxial and negative. It also shows a slight but distinct dispersion of the bisectrices, giving a brownish and a bluish tint on either side of the position of maximum extinction. When separated by Thoulet's solution, the mineral was found to have a specific gravity between 2·48 and 2·44, and to be readily decomposed when heated with dilute hydrochloric acid with the evolution of carbonic dioxide and with subsequent gelatinization. The cancrinite occurs in the nepheline in the form of narrow strings or more rarely in little bunches of grains. These usually follow the course of minute cracks or cleavage lines, but also are frequently seen to follow the boundaries of individual grains of nepheline on their contact with grains of other minerals. Thus between crossed nicols they appear as a brilliant edging about hornblende individuals or about calcite inclusions in the nepheline, the small prismatic individuals of cancrinite being arranged with their longer axes at right angles to the contact or to the course of the crack, as the case may be. The cancrinite has the appearance of being an alteration product of the nepheline.

The Calcite occurs in large single individuals, which are found as inclusions in both the hornblende and the nepheline. The single individuals are often perfectly circular in outline, and the enclosing mineral is perfectly fresh and unaltered and is sharply defined against them. In other cases the same large calcite individuals lie between the other constituents of the rock, in all cases having the character of inclusions. They generally show very marked strain shadows, while the other constituents show but little or no evidence of pressure phenomena.

The Apatite is found as occasional more or less rounded individuals, enclosed in the nepheline or hornblende, but, like the other accessory constituents, merits no especial description.

An analysis of the rock made for me by Mr. M. F. Connor gave the following results:

SiO_2	39·74
TiO_2	·13
Al_2O_3	30·59
Fe_2O_3	·44
FeO	2·19
MnO	·03
CaO	5·75
MgO	·60
K_2O	3·88
Na_2O	13·25
CO_2	2·17
SO_3	trace
Cl	·02
S	·07
H_2O	1·00
	99·86

If, following the methods of the Quantitative Classification, the Norm of the rock be calculated, that is to say the proportion of standard minerals which would give a magma of this composition, or in the form of which the rock under other conditions of cooling might have solidified, this is found to be as follows:

Anorthite	12·51
Nepheline	67·72
Leucite	8·28
Olivine	3·70
Akermanite	·40
Magnetite	·70
Ilmenite	·30
Pyrite	·14
Calcite	4·92
	98·67
Water	1·00
	99·67

This gives the rock the following position in the Quantitative Classification:

Class 1—Persalane.
Order 8—Ontarare.
Rang 2—(Domalkalic).
Sub-rang 4—(Dosodic).

As this is the first Ontarare which has been described, the rangs and sub-rangs have received no names as yet. It is proposed, therefore, to call rang 2, Monmouthase, and sub-rang 4, Monmouthose, from the township of Monmouth in which this rock is found, while, as an ordinary designation, the name Monmouthite may be applied.

The Mode, or actual mineralogical composition of the rock, is quite different from the Norm, as given above, no leucite, anorthite, olivine, or akermanite being actually present. The mode is *abnormative** to a striking degree.

The Mode is as follows:

Albite	1·83
Nepheline	72·20
Sodalite	·28
Cancrinite	5·14
Hornblende	15·09
Hematite	·50
Calcite	3·12
Pyrite	·14
	98·30
Water	·50
Excess of Al_2O_3	1·20
	100·00

In calculating this mode the nepheline is taken as consisting of soda nepheline and kaliophyllite, in the proportions of 5 to 1, which is the composition of the nepheline of the nepheline syenite occurring further to the west in the area of the township of Dungannon.† One-half of the water found in the analysis is considered as being present in the cancrinite, the remainder being regarded as belonging in part to the hornblende and as existing in part as hygroscopic water. This gives cancrinite in about the proportion in which it seems to be present in the thin sections of the specimens analyzed.

The various bases not required by the other minerals and remaining over to form the hornblende, are present in the proportions required to form syntagmatite; which are the proportions in which these bases are found in the hastingsite of the Dungannon nepheline syenite. The hornblende has accordingly been calculated as syntagmatite, using the theoretical values given by Zirkel: Lehrbuch der Petrographie, vol. i, p. 303. This accounts for the existing percentages of all the constituents of the rock, with the exception of an excess of 1·20 per cent of alumina.

Of the rocks hitherto described, those which bear the closest resemblance to Monmouthite are the Urtites of the Peninsula of Kola.‡ These, however, belong to the class of the Dosalanes.

Geological Department, McGill University, Montreal, P. Q.

* See Quantitative Classification (loc. cit.), p. 150.

† B. J. Harrington: loc. cit.

‡ W. Ramsay: Das Nephelinsyenitgebiet auf der Halbinsel Kola, Fennia. 15, No. 2, p. 22.

ART. XXV.—*Note on a Calcite-Prehnite Cement Rock in the Tuff of the Holyoke Range;* by B. K. EMERSON.

AT Lymans Crossing, now abandoned, a mile north of Smiths Ferry, and just south of the river notch through the Holyoke Range, is a large cutting through the posterior trap sheet, exposing the upper surface and the superjacent tuff beds. The cementing material which holds the tuff fragments together at the base of the bed is quite peculiar. It looks like a felsite or a compact sedimentary limestone. It is clear gray with faint shade of green.

The small angular fragments of trap enclosed in this cement are often one to three inches apart, showing that it cannot be a simple secondary interstitial cement produced by a later infiltration. It contains here and there rounded or pear-shaped cavities, filled with coarse calcite, which seem to be certainly steam holes. Minute scales of graphite just visible to the eye are quite generally distributed and are slightly larger and more abundant where the cement rock borders against the trap. The scales are graphite and not molybdenite, since they float in Thoulet's solution.

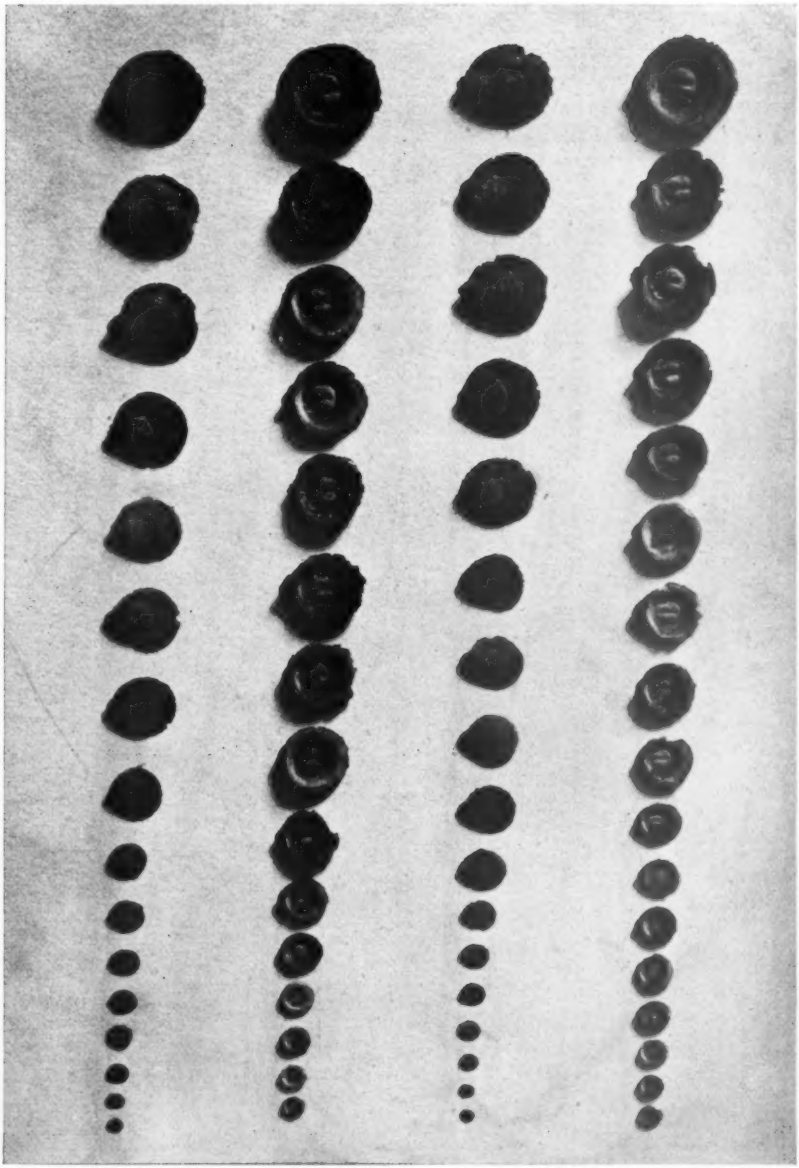
Under the microscope the trap fragments are seen to be normal and to preserve their usual characters up to their borders.

The cement rock has a confused crystalline texture and large stationary black crosses appear everywhere over the surface. It is made up in about equal parts of calcite in shapeless areas with very irregular boundaries, and a colorless prehnite in coarse rudely radiating prisms and wheel-shaped forms which plainly cause the black crosses. A few blades of a pale brown biotite are present but may be secondary. Distinctly secondary are the angular fragments of acid plagioclase and microcline, which have a granitic aspect. The rock has sp. gr. = 2·86, which indicates that a little more than half its mass is prehnite, and the study of the section confirms this. The small crumpled graphite scales are also secondary, and must have come from west of the axis of the Green Mountains, twenty-five miles west, or from the Brinefield rusty schist area fifteen miles east. The brightly shining scales resemble those from the western area. The same graphite is found extensively in the adjoining sandstone. There is also a small amount of a primary albite deposited by the same waters from which the prehnite crystallized and having the same undulose extinction which characterizes the albites deposited by heated waters in the cavities in the trap.

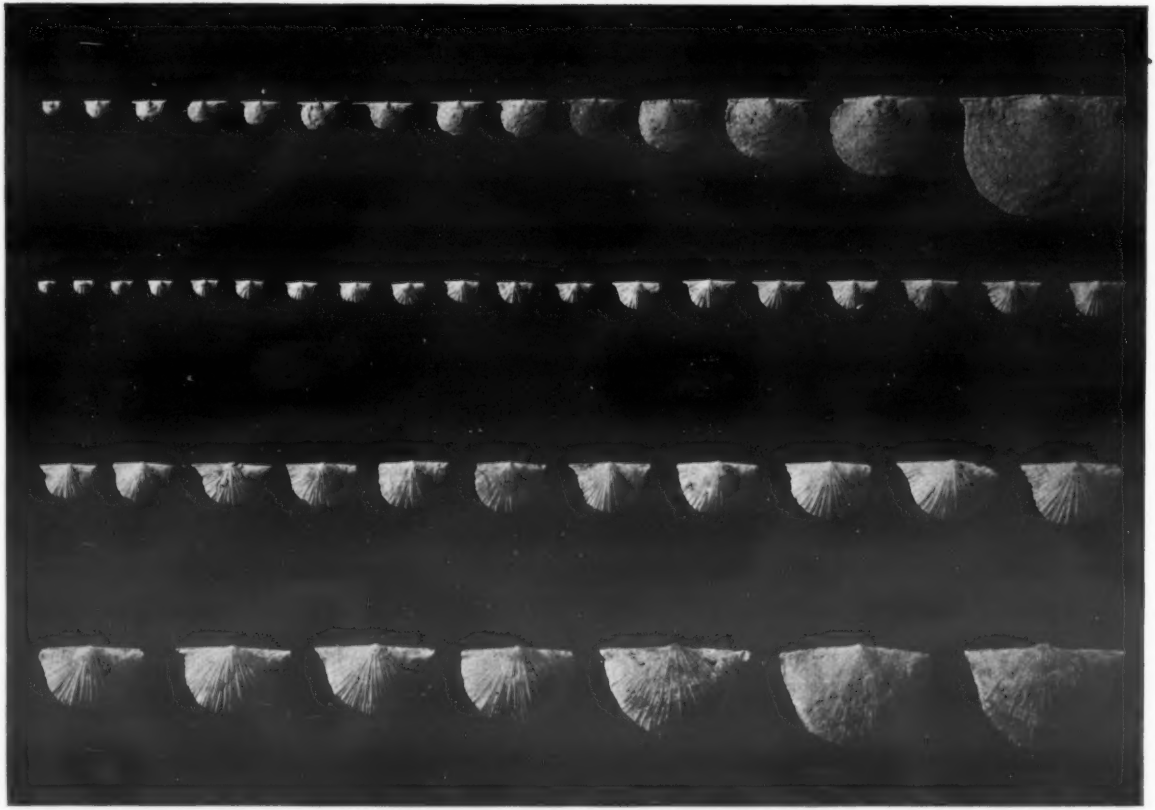
The outburst of the tuff followed immediately on the outflow of the trap sheet and many of the scoriaceous bombs which first fell sank quite deeply into the latter and can be seen enclosed in compact trap as at the western pavilion in Mountain Park.

The cement rock formed at the base of the tuff in waters which were slightly contaminated by the materials of the sandstone, the graphite scales being especially far travelled because of their indestructibility and lightness. It increased to very considerable thickness between the trap fragments and crystallized so rapidly and in such high temperature that it enclosed pear-shaped steam holes like a scoria. After the temperature had fallen below the solution point of prehnite, these cavities were filled by calcite.

Amherst College, Mass.



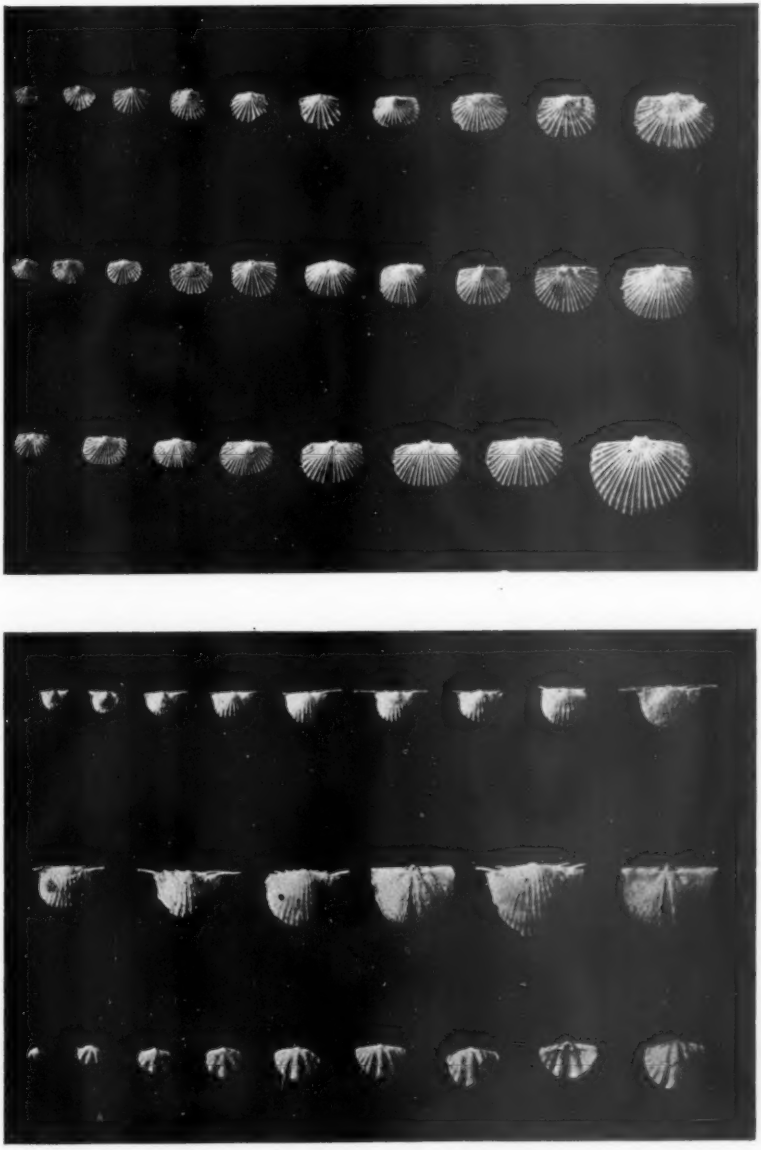
PHOLIDOPS OBLATA Hall. ×2.



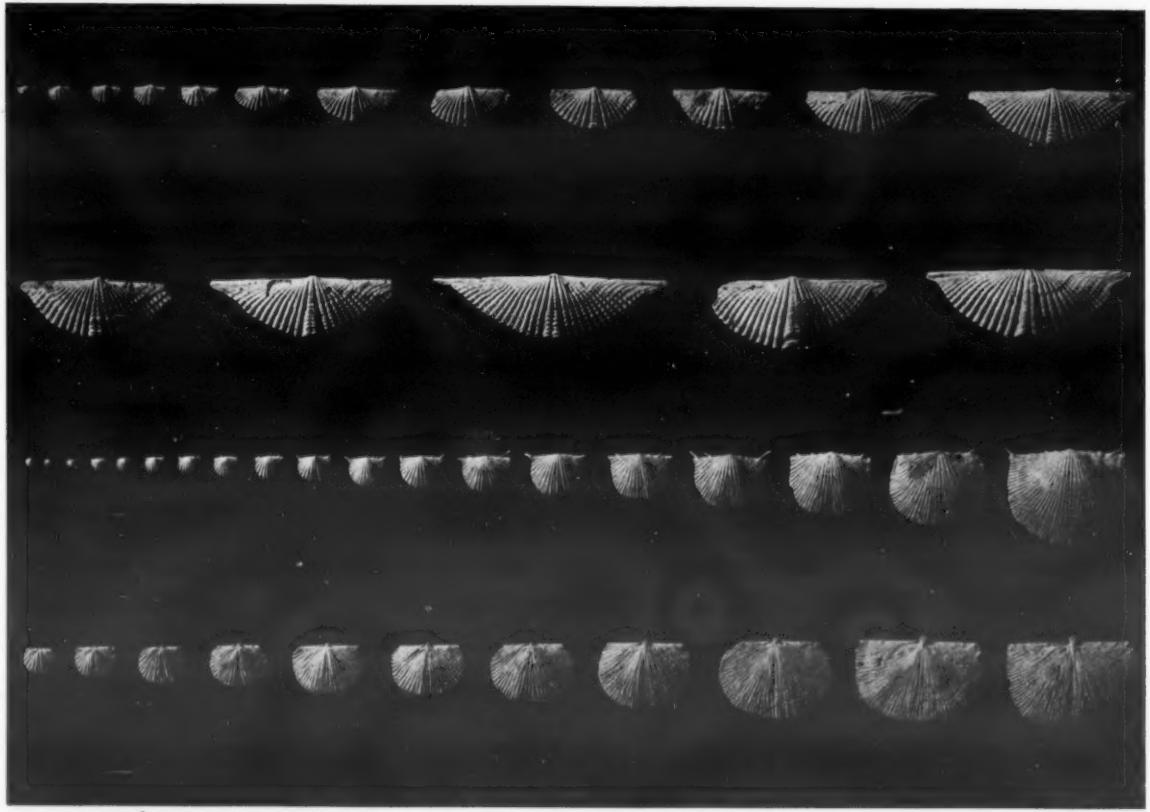
1.—STROPHEODONTA PERPLANA Conrad. ×1.

2–4.—STROPHEODONTA INÆQUISTRIATA Conrad. ×1.

CHONETES SCITULUS Hall. ×2.

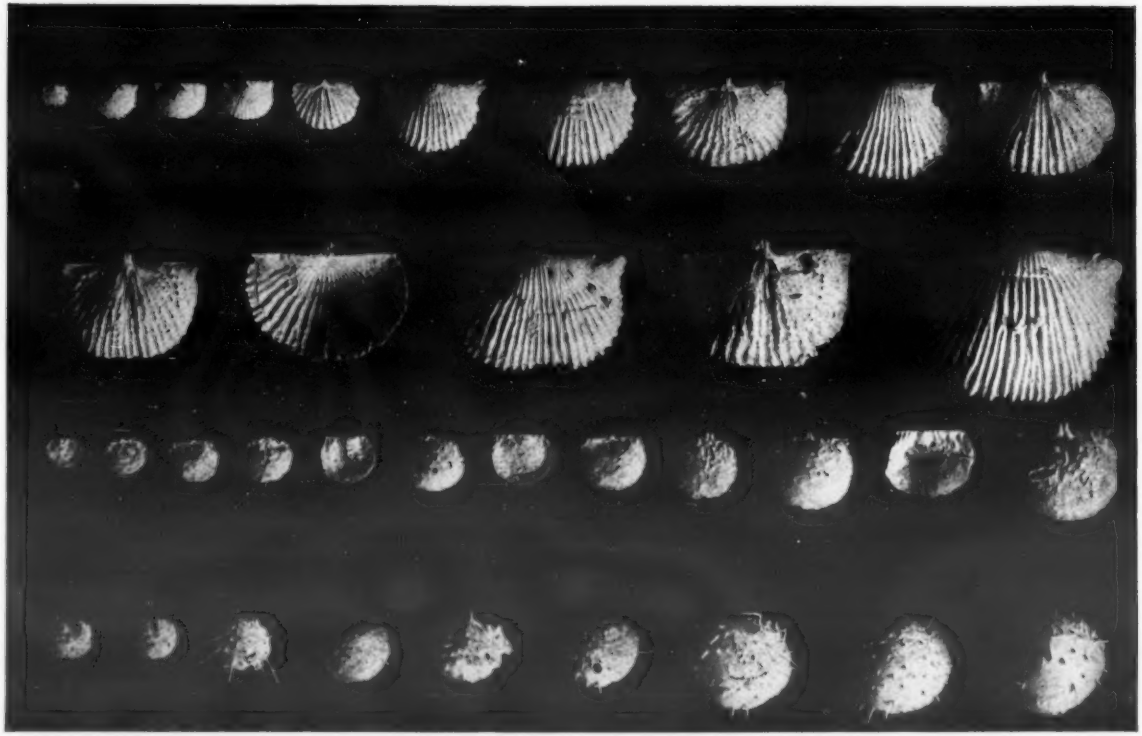


1.—ORTHOTHETES CHEMUNGENSIS var. PECTINACEA Hall. ×2.
2.—ORTHOTHETES CHEMUNGENSIS var. ARCTISTRIATUS Hall. ×2.
3.—ORTHOTHETES BELLULUS Clarke. ×2.
4, 5.—CHONETES MUCRONATUS Hall. ×2.
6.—CYRTINA HAMILTONENSIS Hall. ×2.



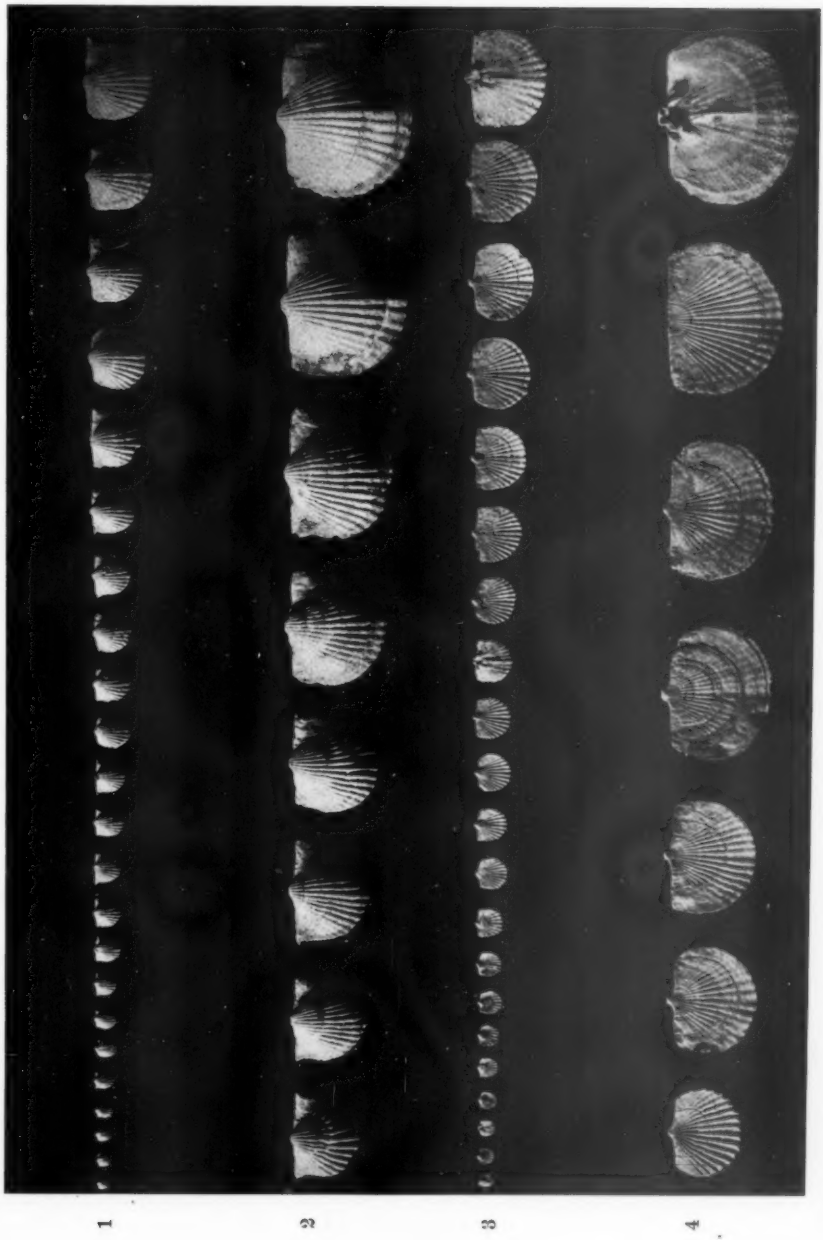
1, 2.—SPIRIFER MUCRONATUS Conrad. ×1.

3, 4.—CHONETES CORONATUS Conrad. ×1.



1, 2.—CHONETES ROBUSTUS Raymond. ×2.

3, 4.—STROPHALOSIA TRUNCATA Hall. ×2.



TROPIDOLEPTUS CARINATUS Conrad.

ART. XXVI.—*The Developmental Changes in some Common Devonian Brachiopods;* by PERCY E. RAYMOND. (With Plates XII–XVIII.)

INTRODUCTION.

CERTAIN layers of impure, clayey limestone from the Moscow (Hamilton) shales which occur in a ravine near Canandaigua Lake, N. Y., were found by Dr. John M. Clarke to contain fossils whose shells had been so completely replaced by silica that when the rock was etched in acid the shells were left in as perfect condition as when they were buried in the limy clay of their native sea-bottom. A large quantity of this material was obtained by Prof. C. E. Beecher, and through his kindness part of it has been placed at the disposal of the writer for study. About 65 pounds of the rock were treated with hydrochloric acid, and the shells washed from the clay which remained after the calcium carbonate had been removed. From this material about 15,000 nearly perfect specimens have been selected, while a much greater quantity of fragmentary material was discarded. Nearly all classes of invertebrate animals are represented in this collection, but the brachiopods are most numerous, comprising two-thirds of the total number of individuals, and furnishing at least thirty-five hundred specimens of a single species (*Chonetes scitulus*). Next in abundance to the brachiopods are the Bryozoa, then the Crustacea, worm tubes, pelecypods, gastropods, corals, and cephalopods, in the order named. The echinoderms are represented only by crinoid columns and the sponges by a few spicules. A few fish scales were also found. Chitinous shells of the *Lingula* type do not appear to have been preserved, and some of the Dimyarian bivalves occur only as casts.

The majority of shells are white, but some are dark gray to black, while the trilobite tests are light to dark brown. The color seems to be fairly uniform for all the individuals of the same species. For instance, there are two species of *Monotrypa*, and all the individuals of both species are black, yet most of the Bryozoa are light colored. In the case of *Chonetes mucronatus*, however, while most of the specimens are dark, a few are white.

The state of preservation of the fossils in this material is remarkable, even the finest details being retained, which shows conclusively that the shells were not subjected to any rough wave action after the death of the animal. The graceful fronds of the Fenestellidæ are obtained as they grew, and the delicate spines of the Productidæ and the spiniform exten-

sions of the cardinal angles of the young *Stropheodonta* are in perfect condition. Unfortunately the brachial loops and spires are not so well preserved, though many specimens of *Eunella* show a large part of the loop, and in one young form it is entire. Many specimens of *Tropidoleptus* retain the delicate median septum and the crura, but the loop was not observed.

Perfect examples of the little ostracods of the genera *Hallielia* and *Kirkbya*, whose shells are merely a fine network, were obtained, as well as many of the *Rhombopora*-like Bryozoa, covered with minute spinules. The pelecypods, which are nearly all immature individuals, are excellently preserved, and many of them retain the prodissoconch.

The advantage of this method of collecting is shown by the great number of specimens of supposedly rare species obtained. *Pholidops hamiltoniæ*, which is rare in ordinary collections, is extremely abundant in this material, only one species being more common. *Pholidops oblata*, of which not more than a dozen specimens have been found in other localities, has here been obtained by the hundreds, while *Ascodictyon stellatum*, *Autodetus Lindstrœmi*, and the ostracods, which are seldom found in any quantity, are very common. The whole fauna consists of about 125 species, 115 of which have been thus far identified, there being 10 or 12 whose specific identity is uncertain, and some of these are probably new. The fauna is distributed as follows:—Crustacea: Trilobita, 5 species; Ostracoda, 11; Cephalopoda, 1; Gastropoda, 8; Pteropoda, 3; Pelecypoda, 16; Brachiopoda, 39; Bryozoa, 18; Vermes, 6; Anthozoa, 5.

A large proportion of the individuals of the Brachiopoda are in immature stages, many of them being less than 1^{mm} in length. From that size there are specimens showing all gradations up to the adult, and, in many cases, to senile stages. Series representing all these stages have been selected wherever possible, and carefully studied, in order to ascertain what changes took place in the shell during the lives of the individuals of the various species.

The pioneer work of this sort was done by Beecher and Clarke on material obtained from Waldron, Indiana. In the memoir published by them giving the results of this work, the developmental stages of 25 species, belonging to 18 genera, were described. Later work by Beecher, Schuchert, and Cumings, has added full descriptions of several more. Among the fossil brachiopods, 2 genera of the Rhynchonellidæ, 3 of the Atrypidæ, 1 of the Craniidæ, 1 of the Eichwaldiidæ, 4 of the Strophomenidæ, 4 of the Orthidæ, and 1 of the Porambonitidæ, have been studied in this way up to the present time.

From the present material the writer has been enabled to study the complete series of changes in 20 other species, and a partial series in 4 more. This list comprises 15 genera, 11 of which are not represented in the work previously done. These genera belong to the families Centronellidæ (*Trigeria*), Terebratulidæ (*Eunella*), Terebratellidæ (*Tropidoleptus*), Spiriferidæ (*Cyrtina*, *Delthyris*), Craniidæ (*Pholidops*, *Craniella*), Strophomenidæ (*Stropheodonta*, *Pholidostrophia*), and Productidæ (*Chonetes*, *Strophalosia*). *Crania*, *Rhipidomella*, *Spirifer*, and *Orthothetes* are here represented by Devonian species, while the previous work has been done on those from the Silurian; interesting points may be therefore obtained by comparing results.

The present paper is an abstract of the results attained from this study, and gives a summary of the most interesting facts ascertained in regard to 17 of these species.

Crania crenistriata Hall.

Pal. N. Y., iv, 1867, p. 28, pl. 3, figs. 13–16.

The smallest specimen of this species is 2·66^{mm} long and 3·33^{mm} wide. At the apex it shows the nepionic shell, which is similar in form to the adult, but non-plicate. It is 1·46^{mm} long by 1·66^{mm} wide. In this species, and in *Craniella hamiltoniæ*, the young shells have, as a rule, more conical dorsal valves than the adults.

Stropheodonta inæquistriata Conrad.

(Plate XIII, Rows 2, 3, and 4.)

Pal. N. Y., iv, 1867, p. 93, pl. 12, figs. 6–8.

Nepionic Stage.—In the nepionic stage the shell of this species is oval in outline, and wider than long. Both valves are convex, though in some specimens the dorsal valve becomes flat in front. The latter valve bears a narrow median fold which extends about half-way to the front. Otherwise the shell is smooth. The length of the average specimen in this stage is ·42^{mm} and the width ·54^{mm}.

Changes during Development: Outline.—Immediately after the nepionic stage the width at the hinge becomes greater than that below, and remains so through all succeeding stages. The cardinal extremities are most alate during the adolescent period, and all immature forms are characterized, when perfect, by long hinge lines. In the senile state, the cardinal angles are not so extended, but the width at the hinge is still the greatest width. (Compare the young specimens, Nos. 14 and 15 of the series, with the adult and senile individuals on Plate XIII, Row 4.)

Convexity of Valves.—In the nepionic stage both valves are convex, but, when a length of about ·5^{mm} is reached, the dorsal valve becomes concave in front and follows very closely the curvature of the other valve throughout succeeding stages. Shells from 1 to 6^{mm} long are very slightly convex, sometimes almost flat, but, as they grow older, the convexity increases until in the gerontic stage they are almost hemispherical.

Muscle Scars.—The migration of the muscles in this species during the life history is most interesting. The normal form of the scars in the ventral valve of the adult is shown in Paleontology of New York, Vol. 4, Plate 15, figure 10, and figure 2h, Plate 18, gives the interior of a dorsal valve at the same stage. Figure 2h, Plate 18, and figure 11, Plate 15, show the ventral and dorsal valves of a senile individual.

In the smallest ventral valve in which the muscles have left distinguishable impressions (4×4^{mm}) the diductors have oval, somewhat widely separated scars, between which are the two small adductors, one on either side of the median line. The diductors are bounded posteriorly by two ridges making a wide angle with each other. The adductor scars have faint ridges on either side and another ridge between them. In a little later stage these three ridges become sharp and distinct. The median one runs nearly to the beak, while the others remain short, sharp, and rather high, curving outward. In the later neanic stages these ridges arch over and join the ridges which bound the diductors.

The two ridges bounding the posterior borders of the diductors send off processes a short distance in front of the hinge, which turn inward and run parallel for a little way. They rise sharply from the floor of the valve, and overhang on the side toward the median line. In the later neanic stages the whole extent of the diductor impressions is bounded by a low, sharp ridge that is later resorbed.

During the adult stage the parallel portions of the two ridges which bound the diductors are extended and strengthened, and the divergent portions resorbed. The median ridge becomes stronger and rounded, and the two sharp ridges which separated the adductors from the diductors disappear. An almost square muscle scar is thus produced, which has less area for attachment of the muscle, but is better located for a direct pull on the cardinal process.

In the dorsal valve the two pairs of adductors occupy a small space in front of the cardinal process, and are usually bounded by a low ridge. The outer pair, the posterior adductors, make up most of the scar. They are small, roughly triangular, and situated close to the front of the cardinal process. The anteriors are narrow, and are situated on a platform between, and

slightly above, the level of the posteriors. Between the scars, on the median line, is a low, short septum which is hardly elevated above the surface of the shell in young specimens, but becomes prominent in adults. On either side of it is a low ridge extending back nearly to the base of the cardinal process. In the adult the portion of these ridges in front of the muscle scars becomes high and incurved, and may function as a support for the brachia. These ridges are short, and their anterior ends are not half-way to the front of the valve. They appear to be homologous with similar ridges in *Chonetes scitulus*, which are certainly connected with the brachia. The structure of the muscle scars and ridges in this species should be compared with that in the dorsal valve of *S. concava*. In neither case do the ridges in front of the muscle scars function as the attachment for muscles, as has been suggested by many writers.

Hinge Structure.—A few of the smaller specimens show a short exsert pedicle tube. In adult and senile stages the pedicle opening is pushed back onto the beak, and is very minute.

Stropheodonta perplana Conrad.

(Plate XIII, Row 1.)

Pal. N. Y., iv, 1867, pp. 92, 98, pl. 11, fig. 22; pl. 12, figs. 13–15.

Protegulum.—The protegulum of this species is nearly circular, biconvex, with arcuate hinge. It measures ·10×·10^{mm} on one specimen, and ·12×·12^{mm} on another.

Nepionic Stage.—The shell in the nepionic stage is convex in both valves, nearly as long as wide, and both valves are smooth. On the dorsal valve is a fold which extends nearly to the front of the shell (figure 1).

Changes during Development.—Like *S. inæquistriata*, this shell becomes strongly alate in the neanic stages and the hinge width remains the greatest width throughout life. (See specimens 4, 7, 10, and 14 of the series, for examples of this.) After the nepionic stage, the dorsal valve becomes first flat and then slightly concave. The shell remains nearly flat throughout all stages.

1

Figure 1. — *Stropheodonta perplana* Conrad; dorsal valve, showing shell in nepionic stage, the fold, and the origin of the striæ. ×16.

Muscle Scars.—In this species there is no change in the position of the muscle impressions during life. The adductor scars in the ventral valve are divided by a diagonal line into anterior and posterior elements, a fact not shown in calcified specimens.

Pholidostrophia iowaensis Owen.

Pal. N. Y., iv, 1867, p. 104, pl. 18, fig. 1.

Changes during Development.—This shell, like the other Stropheodontas, becomes strongly alate in the neanic stages, but the principal change during its development takes place in the adult and early senile stages, when the shell which has formerly been nearly flat is abruptly deflected in front, making the ventral valve very convex in this part, while the dorsal is correspondingly concave. The exterior is smooth in all stages. A single specimen from Eighteen Mile Creek shows a few distant radiating striæ, which may be taken as suggestive of an ancestral character.

FIGURE 2.—*Pholidostrophia iowaensis* Owen; brachial valves, showing muscle scars and brachial ridges. Natural size.

Brachial Markings.—In front of the muscle scars of the brachial valve, there is, on each side of the strong median septum, a crescent-shaped ridge, which turns in rather abruptly as a sort of hook at the anterior end (figure 2). In adults these processes extend about two-thirds the distance to the front of the shell. In the young, they extend somewhat further forward and are more divergent. These ridges correspond, in position, with the brachial ridges of *Chonetes* and *Productus* and probably should be correlated with those markings. They have been given considerable taxonomic importance by some authors, the group of Stropheodontas which bears them being considered by Œhlert as forming a transition group connecting the Strophomenidæ and the Productidæ. It is probable, however, that the occurrence of these markings is due more to the age of the individual shell than to anything else, for with increase in the deposit of testaceous matter the brachial scars become more distinct in those species in which they are usually observed, and these scars are not confined to the Devonian Stropheodontas but can be seen in *Rafinesquina* from as old a formation as the Chazy; they are likewise well known to occur in *R. Jukesii* and *Stropheodonta profunda*.*

The genus *Pholidostrophia* was suggested by Hall and Clarke to include a section of the Stropheodontas in which the shells were concavo-convex, had no striæ, and were strongly punctate. The interior of the dorsal valve was characterized by having three divergent ridges in front of the muscular area. *Stropheodonta nacrea* Hall, from the Corniferous and Hamilton, an unnamed species from the Corniferous, and *Stro-*

*See Hall and Clarke, vol. viii, pt. i, pp. 282, 283, figs. 19, 20; and pl. 20, fig. 30.

phomena lepis Bron., of the Middle Devonian from Eifel, Belgium, and the Asturias, were placed in this division.

The development of the hinge structure, form of shell, and convexity of valves is very similar in the three species (*S. inæquistriata*, *S. perplana*, and *P. iowaensis*) just described. The points of greatest difference are:

First: The Striæ.—*S. inæquistriata* produces new striæ by implantation, *S. perplana* by both implantation and bifurcation, while *P. iowaensis* has normally no striæ at any stage of development.

Second: Muscle Scars.—*S. inæquistriata* has a type very different from that of the other two, and in the ventral valve there is a change in the form of the muscles during the ephebic and gerontic stages. In the other two no such change has been observed.

3

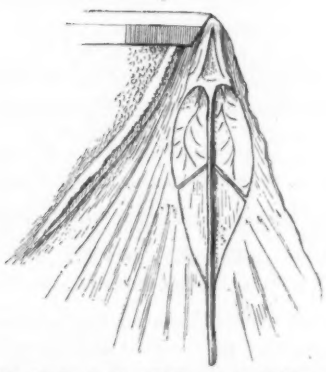


FIGURE 3.—*Stropheodonta junia* Hall; part of the muscle area of a ventral valve, showing the anterior and posterior elements of the adductors, and the pedicle muscle scar. ×3.

Comparing the scars in the ventral valves of *Stropheodonta junia* (figure 3), *S. perplana*, *S. demissa*, and *Pholidostrophia iowaensis*, it is at once seen that they are very similar. In each the diductors are broad, flabelliform, separated by a low septum, and bounded on their posterior lateral edges by more or less papillose ridges. Between the diductors are the elongate scars of the adductors, two pairs in each case. In the dorsal valves of *S. demissa*, *S. perplana*, and *P. iowaensis*, there is more variation in the form of the scars, but it is a variation in the form of the limiting structures rather than in the shape of the scars themselves. In each, there are two pairs of scars, one pair somewhat anterior to and between the members of the other pair. In *S. demissa* and *P. iowaensis*

they are bounded by a low ridge in front, while in *S. perplana* the anterior margin is more indefinite.

The interior of the dorsal valve of *P. iowaensis* should also be compared with that of *S. profunda* Hall, from the Niagara.* In that species the form of the scars is almost exactly the same as in the Hamilton species, and in front of the scars there are two short curved ridges and a prolongation of the median septum. This species has been put in the division Brachyprion by Hall and Clarke.

Thus there are examples of four of Hall and Clarke's subdivisions,—Brachyprion, Leptostrophia, Pholidostrophia, and Stropheodonta (*S. demissa* type), which agree in internal structure, but have great variation in external ornamentation. These facts would seem to indicate that the name Pholidostrophia should be given the same taxonomic value as the names Brachyprion and Leptostrophia, instead of being raised to generic rank.

Orthothetes chemungensis Hall.

Orthothetes chemungensis var. *pectinacea* Hall.

(Plate XV, Row 1.)

Pal. N. Y., iv, 1867, p. 67, pl. 10, fig. 6.

Orthothetes chemungensis var. *arctistriatus* Hall.

(Plate XV, Row 2.)

Pal. N. Y., iv, 1867, p. 71, pl. 9, figs. 1–12.

The specimens of *Orthothetes* in the present collection represent the two varieties *pectinacea* and *arctistriatus* of Hall. Both develop in the same manner, the only difference being in the time of appearance of new striæ. In the adult these two forms can be separated only under the most favorable circumstances, yet the younger specimens are quite distinct. The variety *pectinacea* has from 15 to 19 strong elevated striæ, between which are lower interspaces containing from 1 to 3 striæ. In the variety *arctistriatus* the striæ are so crowded that this alternating appearance is not obtained.

Smallest Shell.—The smallest shell which retains both valves is ·73^{mm} long and 1·1^{mm} wide, with a hinge width of 1^{mm}. Both valves are convex, and the cardinal area is high. The delthyrium is almost completely closed by a strong, convex deltidium which is slightly prolonged at the apex, forming an exsert pedicle tube. On this specimen there are 13 striæ on the dorsal and 14 on the ventral valve. At the beaks can be seen the outline of the nepionic shell, which is almost

* Loc. cit.

exactly circular, biconvex, and smooth. It is ·35^{mm} in length, but varies from that size to ·43^{mm}.

Introduction of New Striæ.—The shell of the variety *pectinacea* has, up to a length of 1 to 1·2^{mm}, from 13 to 15 sharp, simple striæ separated by spaces which are wider than the striæ. There then appear from 4 to 6 new striæ in the middle of the front, one implanted in each interspace in that region (figure 4). Specimen No. 1, on Plate XV, Row 1, shows the shell with the original striæ. Specimen No. 2 shows 5 striæ implanted in front. Later, more are implanted until there is one between each pair of the original striæ. The next step is the appearance of striæ in pairs, one on each side of each of the secondary striæ. (See specimens Nos. 8 and 10, Row 1, Plate XV.) At a still later stage more pairs are added, one on each side of those next previous to appear. In the variety *arctistriatus*, the method of development is the same, but the resulting appearance is somewhat different. In the earliest plicated stages there are from 15 to 19 sharp striæ. New striæ appear as before, but come in at earlier stages, thus covering the surface of the valve more completely and giving a more uniform appearance to the striæ. (Compare No. 6, Row 1, Plate XV, with No. 6, Row 2, and the last specimens in each row.)

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FIGURE 4.—*Orthothetes chemungensis* var., *pectinacea* Hall; dorsal valve, showing earlier plications. ×12.

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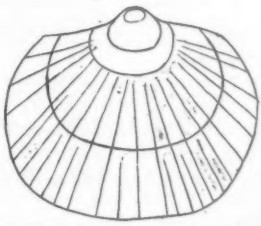

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FIGURE 5.—*Orthothetes chemungensis* Conrad; specimen retaining both valves and showing pedicle tube and simple plications. ×16.

FIGURE 6.—The same species; ventral valve, showing pedicle tube which is somewhat broken at top, growth lines, and striæ. ×16.

Orthothetes bellulus Clarke.

(PLATE XV, ROW 3.)

13th Ann. Rept. N. Y. State Geol., pp. 176, 187, pl. iv, figs. 2–4.

This species was described by Clarke from specimens found in the Marcellus, but the Hamilton forms from the Canandaigua

Lake locality differ only slightly from the type. As described by Clarke, the Marcellus specimens have from 18 to 20 plications; the greatest diameter is at the hinge, and there is no umbonal distortion. The Hamilton specimens, however, have from 24 to 30 plications, the width at the hinge is less than that below, and the cardinal area is high, the ventral umbo being on that account frequently distorted.

The developmental stages offer nothing new. The shell in the nepionic stage is very small, usually from ·10 to ·12^{mm} in length. In young stages there is an exsert pedicle tube, while in the adult a strong convex deltidium covers the delthyrium.

Summary.—The development of two other species of *Orthothetes* has been worked out: That of *O. subplanum* of the Niagara, by Beecher and Clarke,* and that of *O. minutus* of the Salem limestone, by Cumings.† *O. bellulus* has in its adult stage many characters which agree with the neanic stages of *O. minutus*. The latter species has, in its earliest plicated stage, 18 plications, and more are added in the same way as in *O. bellulus*. In the adult, dwarfed, there are 40 plications.

Comparing the development of *O. subplanum* of the Niagara with that of *O. chemungensis*, many differences are found.

First: Convexity of Valves.—The nepionic shells of *O. chemungensis* have the valves subequally convex, which is the adult state of *O. subplanum*, while its nepionic shell is concavo-convex.

Second.—In *O. subplanum* the cardinal area is low compared with the length of the hinge line and the adults are symmetrical. In *O. chemungensis* only in the early neanic stages are the shells perfectly symmetrical usually, though some specimens retain the low cardinal area and symmetry into the late neanic stages.

Third: Surface Characters.—The duration of the nepionic stage is about the same in both species. In the youngest specimen of *O. subplanum* figured by Beecher and Clarke, 2·25^{mm} long, there are 17 striæ, 6 of which are secondary. A specimen of *O. chemungensis* of similar length has from 28 to 35 striæ.

Fourth: Hinge Structure.—The young of both species have a strong convex deltidium which is prolonged into an exsert tube for the passage of the pedicle. In *O. subplanum* the deltidium ceases to grow at an early stage, while in *O. chemungensis* the deltidium continues to increase in size throughout all the stages.

* Silurian Brachiopoda. Memoirs N. Y. State Museum, vol. i, No. 1, 1889, p. 23, pl. ii, figs. 14–20.

† Am. Geol., vol. xxvii, March, 1901, p. 147, pl. xv, figs. 1–11.

The first three of these differences point to an earlier acquisition of the characters through acceleration. The last would tend to show that *O. chemungensis* was in a progressive rather than a retrogressive line of development.

Chonetes coronatus Conrad.

(Plate XVI, Rows 3, 4.)

Pal. N. Y., iv, 1867, p. 133, pl. 21, figs. 9–12.

Chonetes scitulus Hall.

(Plate XIV.)

Pal. N. Y., iv, 1867, p. 130, pl. 21, fig. 4.

Chonetes mucronatus Hall.

(Plate XV, Rows 4, 5.)

Pal. N. Y., iv, 1867, p. 124, pl. 20, fig. 1; pl. 21, fig. 1.

Chonetes robustus sp. nov.

(Plate XVII, Rows 1, 2.)

The New Species.—There are in the collection from Canandaigua Lake about 50 specimens of a *Chonetes* which differs in important characters from any described species. The shell is strongly concavo-convex, wider than long, with from 20 to 40 strong, sharp, equal striæ which increase toward the front by bifurcation and implantation. The umbo is smooth for a distance of from 1 to 2·5^{mm}, cardinal area of ventral valve narrow, concave, and the delthyrium covered by a convex deltidium. Pedicle opening minute, encroaching upon the ventral beak. The posterior margin of the area bears from 4 to 6 pairs of short divergent spines. For this species the name *Chonetes robustus* is suggested.

This species is more nearly related to *Chonetes coronatus* than to any other known brachiopod. It differs from it in the smaller size of the adult, the much greater convexity of the ventral valve, the fewer and coarser striæ at the same stage of growth, the smoothness of the umbos, the fewer pustules on the interior of the dorsal valve, and the later emergence of the first spines on the posterior margin. On the adult of this species there are 6 striæ in the space of 5^{mm} on the front, while in *C. coronatus* there are 11. In convexity and size this species resembles *C. mucronatus*, but is easily distinguished by the sharpness of the striæ and the angle of divergence of the spines.

The figures on Plate XVII are all enlarged two diameters.

Summary.—All the species in the collection have the same type of changes in development; hence they will be discussed together.

Protegulum.—The shell at this stage is exceedingly small and in none of the specimens of the present material are the beaks well enough preserved to show the protegulum. From Beecher's work it is known that in *C. scitulus*,* the protegulum is nearly circular in outline (·117^{mm} long and ·111^{mm} wide, according to the figure), with a strongly arcuate hinge.

Nepionic Stage.—The species agree in having the shell at this stage convex in the ventral valve, convex at the umbo, and concave or flat in front on the dorsal valve. This is an advance on the condition in *Stropheodonta*, where the dorsal shell is convex during the whole of the nepionic stage.

The ventral valve always has a narrow sinus, and the dorsal valve a corresponding median fold, with usually two less definitely marked lateral folds.

The outline is subcircular, though the width is frequently a little greater than the length. The hinge is somewhat arcuate. The length of the nepionic shell varies considerably in the different species, but is always less than one millimeter. It is least in *C. coronatus* and greatest in *C. mucronatus*.

7

FIGURE 7.—*Chonetes scitulus* Hall; ventral and dorsal valves, showing fold and sinus and plications of very young specimens. ×12.

Pauciplicate Neanic Stage.—In this stage new striæ are introduced by implantation and not by bifurcation of the older ones. The striæ are strong, simple, and separated by spaces as wide as the striæ themselves. The number of plications is not great. In *C. coronatus* and *C. scitulus* the largest number is usually 13 on the ventral valve and 12 on the dorsal. In the other species there are more, but usually less than 20.

The shell is about one-fifth wider than long and gently concavo-convex. The first spines, usually two or three pairs, appear during this stage. The size of the shell at the end of this stage, that is, when the striæ begin to bifurcate, is least in *C. scitulus*, when it is about 2^{mm} long, and greatest in *C. robustus*, where a length of 6·5^{mm} is reached. (See specimens Nos. 1–9, Plate XVI, Row 3; Nos. 1–6, Plate XIV, Row 1; Nos. 1–7, Plate XV, Row 4; Nos. 4, 6, 7, Plate XVII, Row 1.)

Later Neanic and Ephebic Stages.—It would be difficult to make any sharp line which would mark the end of the adolescent period and the assumption of all the adult characters. The size, convexity of valves, and number of striæ continue

* This Journal, vol. xli, 1891, p. 357, pl. xvii, fig. 14.

to increase during these stages, the width becomes greater in proportion to the length, and a number of pairs of spines are added on the cardinal margin.

Gerontic Stage.—Senile characters are not well shown except in *C. mucronatus.* In all, this stage seems to be accompanied by a thickening of the shell, a deepening of the muscle scars, and a growth of the anterior part of the shell, thus reproducing the early neanic conditions of length almost equal to breadth, and an increase in the convexity of the ventral valve.

Strophalosia truncata Hall.

(Plate XVII, Rows 3, 4.)

Pal. N. Y., iv, 1867, p. 16, pl. 23, figs. 12–24.

Nepionic Shell.—Owing to the deformation of the ventral beak resulting from the method of attachment, very little can be made out concerning that valve in the youngest stages except that it is regularly and moderately convex. The beaks of some of the dorsal valves are extremely well preserved and show well the outlines of the protegulum and nepionic shell. The protegulum is transversely oval, with a gently curved posterior margin. In the best preserved specimen it is ·13^{mm} long and ·155^{mm} wide. The dorsal valve of the nepionic shell is subcircular in outline, with the hinge width about equal to the greatest width below. It is convex on the umbo and often for its whole length, though it is sometimes concave in front. The surface is smooth, without spines (figure 8).

Spines.—After the nepionic stage, spines are developed on both valves, but more numerously on the ventral valve. On the dorsal valve they are generally broken off close to the base. One specimen, however, retains two of the spines, which are long, slender, and lie against the surface of the valve. (See Plate XVII, Row 3, No. 11.) On the ventral valve they are better preserved. They are most abundant along the cardinal margin and stand erect, curving in toward each other from opposite sides of the beak, which suggests that they may have been of use in anchoring the shell. Over the rest of the surface the spines are directed forward.

Figure 8.—*Strophalosia truncata* Hall; dorsal beak, showing protegulum and nepionic shell. ×16.

Anal Opening.—On the dorsal valve there is a convex chilidium, at the apex of which is the minute anal opening. The inner opening of this tube is at the anterior base of the cardinal process, just in front of the point where it bifurcates. (See Nos. 10 and 12, Row 3.) The cardinal process undergoes considerable change during the life stages. In early neanic stages

it is wider than long, projects little beyond the hinge line, and is divided once. In the adult it is longer than wide, deeply bifurcated in front, and quadrifid on the posterior face. (Compare Nos. 3 and 6, Row 3, with No. 12.)

Tropidoleptus carinatus Conrad.

(Plate XVIII.)

Pal. N. Y., iv, 1867, p. 407, pl. 62, figs. 2, 3.

Nepionic Shell.—In the nepionic stage, the shell of this species is transversely oval to subcircular, with a hinge width less than the width below. Both valves are convex and smooth. In the early part of this stage the shell is distinctly wider than long, but just before the inception of the plications the length and breadth are about equal.

Changes during Development: Outline.—In the earliest neanic stages the shell becomes longer than wide, and this form is maintained until the shell reaches a length of from 4 to 7^{mm}, after which the width is greater than the length. (Compare the first ten specimens of the series with the last four on Plate XVIII.) From the early neanic through the adult stages the width of the shell at the hinge is greater than the width below, and the cardinal extremities are usually mucronate. In senile stages the width continues to increase without a corresponding growth on the posterior margin, which produces rounded cardinal extremities and gives the shell a transversely elliptical shape.

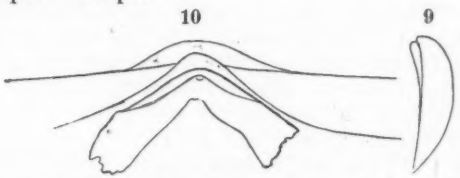

Figure 9.—*Tropidoleptus carinatus* Conrad; profile view, showing relative convexity of valves. ×9.

Figure 10.—Beaks of another specimen, showing pedicle opening and the wearing away of the ventral beak. ×6.

Convexity of Valves.—Up to a length of from ·75 to 1^{mm} both valves are slightly convex, with the pedicle valve somewhat the deeper. At this point, where the plications generally begin, the brachial valve becomes slightly concave, and continues so through the later stages (figure 9).

Plications.—Immediately after the nepionic stage plications arise on both valves, and apparently several are formed at once. On an individual $1{\cdot}6^{mm}$ in length there are 10 plications on the dorsal valve and 9 on the ventral. New plications

are added at the sides and never implanted, nor do they ordinarily bifurcate. In the adult there are from 17 to 21.

Gerontic Stage.—The senile characters in this species are: Hinge width less than the width below; strong varices of growth numerous; obliteration of the plications toward the front of the shell. The plications become flattened and indistinct toward the front of shells over 20^{mm} long.

Cardinal Process.—The cardinal process is large and prominent. It is joined in front to the bases of the crura and between them is a thickening of the shell, forming a platform which slopes forward to the floor of the valve. (See last figure on Row 3, Plate XVIII.) The posterior face of the process is smooth and rounded, and the lower third is covered by a strong chilidium, which also bounds the posterior ends of the dental sockets. The posterior wall of the cardinal process has, near the top, a narrow, rounded sinus formed by a shelly loop, which is continued forward and downward till it unites with the platform. On either side of this process is a deep conical hole, which extends nearly to the apex of the shell and probably represents the place of attachment of the diductor muscles. (See last figures on Rows 3 and 4, Plate XVIII. The platform has been broken away from the specimen at the end of Row 4, but the loop in the middle of the process and the two holes are well shown.)

Directly in front of the loop is a groove in the platform leading back to a minute anal tube, which runs along the middle line of the process and has its external opening in a pore just at the point where the chilidium meets the apex of the valve.

Trigeria lepida Hall.

Pal. N. Y., viii, pt. 2, 1893, p. 274, pl. 50, figs. 36–40.

Description of Smallest Specimen.—The smallest individual of this species is roughly triangular in outline, the rostrate beak, which projects ·25^{mm} beyond the hinge, forming the apex. The ventral valve is convex and smooth, without fold or sinus. The delthyrium is narrow and open. The dorsal valve is convex, and has a deep, narrow median sinus. The length of this shell is 1·09^{mm} and the width ·93^{mm}. This form is very suggestive of the adult *Centronella* (figure 11).

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FIGURE 11.—*Trigeria lepida* Hall; young individual, before the inception of plications. ×16.

In the older specimens the beak is less prominent and in specimens more than 3·5^{mm} long the dorsal sinus becomes obliterated and both valves are convex. Shells more than

1·5^{mm} long have plications, the number increasing from 7 on a specimen of that length to about 18 on a specimen 5·5^{mm} long.

12

FIGURE 12.—*Trigeria lepida* Hall; series showing the growth of the deltidial plates and the encroachment of the pedicle upon the ventral beak. ×8.

Deltidial Plates.—None of the specimens less than 3^{mm} long show any deltidial plates. In succeeding stages the plates appear as narrow triangles, one on each side of the delthyrium, and these triangles gradually become broader until they meet at the base. In the meantime, the pedicle encroaches upon the ventral beak so that an oval pedicle opening is formed in the adult (figure 12).

Eunella Lincklaeni Hall.

Pal. N. Y., iv, 1867, p. 397, pl. 60, figs. 49–65.

The list of changes in the form of this shell is not complete enough to offer anything new, but there are one or two interesting points in connection with the species.

Punctæ.—On the dorsal beak of the smallest shell (1·17^{mm} × ·84^{mm}) the first punctæ can be seen, and their arrangement agrees with that seen on the nepionic shell of *Terebratulina septentrionalis.** The first pair of punctæ is ·07^{mm} from the

13 14 15

FIGURE 13.—*Eunella Lincklaeni* Hall; part of the loop of an adult specimen. ×8.

FIGURE 14.—Centronelliform stage of the loop. ×8.

FIGURE 15.—Side view of specimen shown in Figure 14; shell broken away to show the loop. ×16.

beak, and in front of them, on the median line, is a third one. Beyond this they are scattered sparingly over the surface for a

* E. S. Morse, Memoirs Boston Soc. Nat. Hist., vol. v, No. 8, 1902, pl. 62, fig. 15; also vol. ii, pt. i, No. 2, pl. 1, fig. 3.

short distance, but toward the front of the shell they become very numerous.

Brachidium.—The smallest specimen retaining the brachidium, and the only one in which the loop is complete, is about 4^{mm} in length. The loop extends about half-way to the front of the valve. The primary lamellæ run sharply upward and forward, and the anterior portions run about parallel to the floor of the valve, meeting at the front in an acute angle. As the two lamellæ approach each other they become wider, and, where they join, there is also a point directed backward (figures 14, 15). This is evidently an immature condition of the loop and differs greatly from the loop of the adult of this species. It agrees with the centronelliform stage of loop as described by Beecher and Schuchert.* This is the second genus of brachiopods in which this stage of loop has been observed, and its presence serves to confirm the view expressed in the paper referred to, that the *Centronella* form of loop is a primitive one for this superfamily of brachiopods. It differs slightly from the loop of *Dielasma turgida*† in that the lamellæ are narrower and the angle in front is less acuminate.

Cyrtina hamiltonensis Hall.

(Plate XV, Row 6.)

Pal. N. Y., iv, 1867, p. 268, pl. 27, figs. 1–4; pl. 44, figs. 26–33, 38–52.

Nepionic Stage.—The smallest individual in the collection represents this species in the nepionic stage. The shell is nearly circular in outline, and the length and breadth are the same,—·53^{mm} (figure 16). The hinge line is ·32^{mm} long and

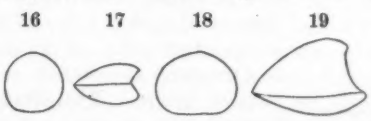

Figure 16.—*Cyrtina hamiltonensis* Hall; outline of the smallest specimen. ×28.

Figure 17.—A larger specimen; profile. ×16.

Figure 18.—The same; outline. ×16.

Figure 19.—A slightly older individual, showing the rapid change in the relative convexity of the valves. ×16.

nearly straight. The beaks of the two valves are elevated above the hinge line, and between them is the pedicle opening, which is shared by both valves. The valves are subequally convex and smooth, with no trace of fold or sinus (figures 17, 18).

* Proceedings Biol. Soc. Washington, vol. viii, p. 73, pl. x, fig. 1.

† Loc. cit.

Changes during Development: Convexity of Valves.—When the individuals become about ·75^{mm} in length the valves are still nearly equally convex, and the ventral area is curved and inclined backward, so that the beak of that valve projects beyond the beak of the dorsal valve. In stages but little later, when the shell is slightly over 1^{mm} in length, the ventral valve is four or five times as deep as the dorsal, and the ventral area becomes more erect, so that the beak is anterior to the hinge line.

Plications.—When the shell has reached a length of from ·45 to ·60^{mm} a sinus is formed in the ventral valve and very soon after its initiation a fold is produced in the opposite shell. This stage, in which there is no other ornamentation than the fold and sinus, continues for some time. The largest specimen showing this state is 1·5^{mm} long and 2·26^{mm} wide. Shells at this period are almost globular and difficult to separate from the young of *Ambocœlia umbonata* unless carefully examined. (See No. 1, Row 6, Plate XV.)

The plications are introduced in pairs on the lateral margins, each pair coming in outside the older ones.

Spirifer mucronatus Conrad.

(Plate XVI, Rows 1, 2.)

Pal. N. Y., iv, 1867, p. 216, pl. 34, figs. 1–32.

Delthyris consobrinus d'Orbigny.

Pal. N. Y., iv, 1867, p. 222, pl. 35, figs. 15–23.

As the development of these two species is practically the same, they will be considered together.

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Figure 20. — *Spirifer mucronatus* Conrad; outline of protegulum and shell in nepionic stage; taken from a dorsal valve. ×28.

Protegulum.—On the beak of a well-preserved dorsal valve of *S. mucronatus* is the impression of the initial shell. It is circular, somewhat convex, with a curved hinge. The diameter is ·11^{mm} (figure 20).

Nepionic Shell.—In the nepionic stage the shell is oval in outline, and broader than long. Both valves are convex, the ventral a little the deeper. The hinge width is less than the greatest width below. The surface is smooth, with no fold, sinus, or plications.

Neanic Stages.—In the earliest neanic stages a sinus is developed in the ventral valve, bounded by two strong ridges, which are the first plications. Following this a fold is formed in the dorsal valve and plications are added on the margins in pairs, each pair coming in outside the older ones. The later plications do not reach the beak.

In an early neanic stage the hinge width is the greatest width of the shell, the cardinal extremities soon become acuminate, and nearly all adolescent shells more than 5 or 6^{mm} wide are strongly mucronate. (Compare the first three shells of the series on Plate XVI with the older ones; also observe the growth lines on specimen No. 3, Row 2.)

It is interesting to note that in their early neanic stages these transversely elongated Devonian Spirifers pass through forms which correspond to the adult condition of certain Niagara species. The adult of *Spirifer crispus*, with a fold and 8 plications on the dorsal valve, and a hinge width nearly equal to the width below, corresponds very closely in these particulars, and in its index, with a specimen of *Spirifer mucronatus* about 2^{mm} long, and, except in the number of plications, with the specimen of *Delthyris consobrinus* 1^{mm} long.

Spirifer radiatus, with no plications, the width only one-seventh greater than the length, and the width at the hinge less than the width below, corresponds to a still earlier stage in the development of the present species.

Summary.

The foregoing descriptions show that the general deductions which have been previously drawn as to the character of the nepionic shell, the development of the pedicle tube and the deltidial plates, and the acquirement of surface characters, hold good in the families here studied for the first time. Other general facts will be noted under the families.

Centronellidæ.—The shape of *Trigeria lepida* in the nepionic stage is almost exactly that of adult *Centronella*, and thus another bit of evidence is added to that afforded by the loop, showing its relation to the Centronellidæ rather than to the Terebratulidæ. Going back to the very earliest stage, before the development of the dorsal sinus, the shell has characters common to the superfamily, that is, a biconvex shell with the ventral beak extended beyond that of the dorsal valve.

Terebratulidæ.—*Eunella*, in its early stages, is a rather simple, generalized type of shell, not differing greatly from the very youngest stage of *Trigeria*, but the development of its loop shows progress beyond the centronelliform stage. The position of the first three punctæ, which is the same as that in the recent genus *Terebratulina*, is interesting.

Terebratellidæ.—The evidence that *Tropidoleptus* belongs to this family has not been strengthened or diminished by the present studies. It still rests on the form of the loop as described by Hall, and later verified by Hall and Clarke. The development is similar to that of the Strophomenidæ, and the

articulation is like that in *Chonetes*. No deltidial plates are developed, and the pedicle is probably functional throughout life. The cardinal process is very large, and of a peculiar type, quite different from that of any of the Strophomenidæ.

Spiriferidæ.—The marked difference in shape and relative convexity of valves of *Cyrtina* in the early neanic stage, from *Spirifer* and *Delthyris* in the same stage, together with the geological range, would seem to indicate that, while both may be derived from the same ancestral stock, *Cyrtina* is not a modified *Spirifer*. *Delthyris*, *Spirifer*, *Ambocœlia*, and *Cyrtina* all start out with an equivalve nepionic shell and a pedicle opening shared by both valves. But with the first changes in later nepionic and early neanic stages, when the fold and sinus appear, *Cyrtina* and *Ambocœlia* become strongly inequivalve, while in *Spirifer* and *Delthyris* the valves retain for a short time their equality of convexity. In other words, the generic habit is assumed immediately after leaving the form that is common to all the members of the superfamily, and *Cyrtina* passes through no *Spirifer*-like stage.

Spirifer and *Delthyris* are so exactly alike in their external form in the youngest neanic stages that it is impossible to separate them.

Strophomenidæ.—The biconvex nepionic shells of *Stropheodonta*, with a median dorsal fold and ventral sinus (which may or may not be present), and the similar nepionic shells of *Chonetes* indicate a possible common origin in some shell of the *Triplecia* type, though not perhaps in that genus which thus far has not been found below the Calciferous, while *Rafinesquina*, which would seem to be the immediate ancestor of *Stropheodonta*, extends into the Chazy and probably lower, without any marked change in form. The early neanic stages of *Stropheodonta*, before the appearance of the crenulations on the hinge margin, are very similar to the adult *Rafinesquina*.

An interesting feature in the development of *Stropheodonta* is the marked mucronation of the cardinal extremities of the adolescent specimens. This mucronation disappears to a greater or less extent in the older stages. This same thing is noticed in *Spirifer*, and there many of the adults retain the mucronate forms, but they are only a phase in the life of the genus. In the ontogeny the outline changes from rounded forms in the nepionic and early neanic stages, through a mucronate form in the later neanic, and back to a rounded form in the adult or senile condition. The same things occur in the phylogeny of *Spirifer*, at least, for there are Niagara species with rounded cardinal extremities, then a great development of the mucronate types in the Lower and Middle Devonian, and a return to the rounded forms in the Carboniferous. A similar change is seen in *Platystrophia*.

The difference between the varieties *pectinacea* and *arctistriatus* of *Orthothetes chemungensis* is a good example of the effect of acceleration in the development of certain characters. The steps in the development of the two are exactly the same, but because the striæ are introduced at an earlier stage on one than on the other, the shells differ greatly in appearance.

Productidæ.—The facts in the development of *Chonetes* do not seem to support the idea put forward by Hall and Clarke that *Chonetes* might be descended from *Plectambonites*, a shell which in many respects much resembles *Chonetes*. The early neanic stages have an outline which is much the same as that of *Rafinesquina* and *Stropheodonta*. The resemblance of the nepionic shell to *Triplecia* has already been referred to, and this, with the other characters, relates the shell to the Strophomenidæ. It is clearly a transition form between the latter family and the Productidæ.

Paleontological Laboratory,
Yale University Museum,
January 6, 1904.

EXPLANATION OF PLATES.*

Plate XII.

Pholidops oblata Hall.

Rows 1 and 2.—Series of dorsal valves. × 2.
Rows 3 and 4.—Series of ventral valves. × 2.

Plate XIII.

Row 1.—Partial series of *Stropheodonta perplana* Conrad; ventral valves. Specimens Nos. 3—9 show well the mucronate cardinal extremities of the adolescent individuals.
Rows 2–4.—Series of *Stropheodonta inæquistriata* Conrad; ventral valves, showing the shells in neanic, ephebic, and gerontic stages.

Plate XIV.

Chonetes scitulus Hall.

Rows 1 and 2.—Series of ventral valves. × 2.
Rows 3 and 4.—Series of dorsal valves; interior view. × 2.
Specimens Nos. 1 and 2 of Row 1, and Nos. 1 and 2 of Row 3, show the ventral sinus and dorsal fold of the very young stages. Most of the specimens in Row 4 show the brachial scars.

Plate XV.

Row 1.—Partial series of *Orthothetes chemungensis* var. *pectinacea* Hall; dorsal valves. × 2.
Row 2.—Partial series of *Orthothetes chemungensis* var. *arctistriatus* Hall; dorsal valves. × 2.

* Unless otherwise stated, the figures are natural size.

Row 3.—Partial series of *Orthothetes bellulus* Clarke; dorsal valves. ×2.
Rows 4 and 5.—Series of *Chonetes mucronatus* Hall; ventral and dorsal valves. ×2.
Row 6.—Series of *Cyrtina hamiltonensis* Hall; dorsal valves. ×2.

Plate XVI.

Rows 1 and 2.—Partial series of *Spirifer mucronatus* Conrad; dorsal valves.
Row 3.—Series of *Chonetes coronatus* Conrad; ventral valves, exterior.
Row 4.—The same; dorsal valves, interior.

Plate XVII.

Rows 1 and 2.—Series of *Chonetes robustus* Raymond; ventral and dorsal valves. ×2.
Rows 3 and 4.—Series of *Strophalosia truncata* Hall; dorsal and ventral valves. ×2.

Plate XVIII.

Tropidoleptus carinatus Conrad.

Rows 1 and 2.—Series of ventral valves.
Rows 3 and 4.—Series of dorsal valves.

ART. XXVII.—*Studies in the Cyperaceæ;* by THEO. HOLM.

XXI. New or little known species of *Carex*. (With figures in the text, drawn by the author.)

Carex neurochlæna sp. n. (figs. 1–2).

RHIZOME slender, ascending, stoloniferous, the leafsheaths persisting, light brown; leaves shorter than the culms, very narrow, carinate, scabrous; culms up till 24^{cm} in height, curved, almost capillary, trigonous, scabrous below the inflorescence, otherwise glabrous, phyllopodic; spikes two to four, gynæcandrous or the lowest one sometimes purely pistillate (fig. 1), small and few-flowered, roundish, contiguous or the lowest one remote, reddish brown, the bracts inconspicuous or the lowest one with a filiform blade much shorter than the inflorescence; scales broadly ovate, those of the staminate flowers acute, the others obtuse, reddish brown with green midrib and hyaline margins; perigynium (fig. 2) longer, but narrower than the scale, sessile, slightly spreading, broadly elliptical, attenuated at both ends, plano-convex, wingless, prominently nerved, greenish, the beak short, slit on the convex face; stigmata two.

Collected above Rink rapids, Yukon River in Yukon, by Professor John Macoun (No. 53,879).

This species belongs to the *Neurochlænæ*.

Carex vagans sp. n.

Rhizome horizontally creeping, forming dense mats, the leaf-sheaths persisting, light brown; leaves glaucous, shorter than the culms, very narrow, carinate, scabrous; culms numerous, from 20 to 30^{cm} in height, very slender and weak, triangular, scabrous, phyllopodic; spikes three to five, androgynous or the lateral purely pistillate, small and few-flowered, sessile, forming an interrupted, spicate inflorescence about 2^{cm} in length, the bracts short and inconspicuous; scales ovate, acute, reddish brown with green, broad midrib and hyaline margins, shorter than the perigynium; perigynium sessile, somewhat spreading at maturity, ovoid, plano-convex, wingless, two-ribbed (the marginal), light brown, minutely scabrous along the very short beak, deeply slit on the convex face; stigmata two.

Collected in Oregon: Steins Mts., flat opposite Andrews, alt. 1950^{m}, by Mr. John B. Leiberg (No. 2558).

In aspect much like *C. occidentalis* Bail., but in this the spikes are more dense-flowered, the perigynium elliptical, stipitate, spongious at the base and the beak prominently bidentate.

Carex phæolepis sp. n.

Rhizome short, creeping, the leaf-sheaths persisting, light brown; leaves light green, a little shorter than the culms, narrow, but flat, scabrous; culms not numerous, from 25 to 35^{cm} in height, slender, but stiff, erect, triangular, scabrous, phyllopodic; spikes four to eight, androgynous and the staminate portion very prominent in all of these, ovate, rather small, sessile and contiguous or the lower ones remote, the bracts inconspicuous; scales ovate-lanceolate, mucronate, light brown with broad hyaline margins and greenish midvein, longer than the perigynium; perigynium almost sessile, erect, broadly elliptical, plano-convex, wingless, two-ribbed (the marginal), colorless, minutely scabrous along the short beak, which is slit on the convex face; stigmata two.

Collected in Eastern Oregon: Bear Butte, Crook County, alt. 1710^{m}, by Mr. John B. Leiberg (No. 335).

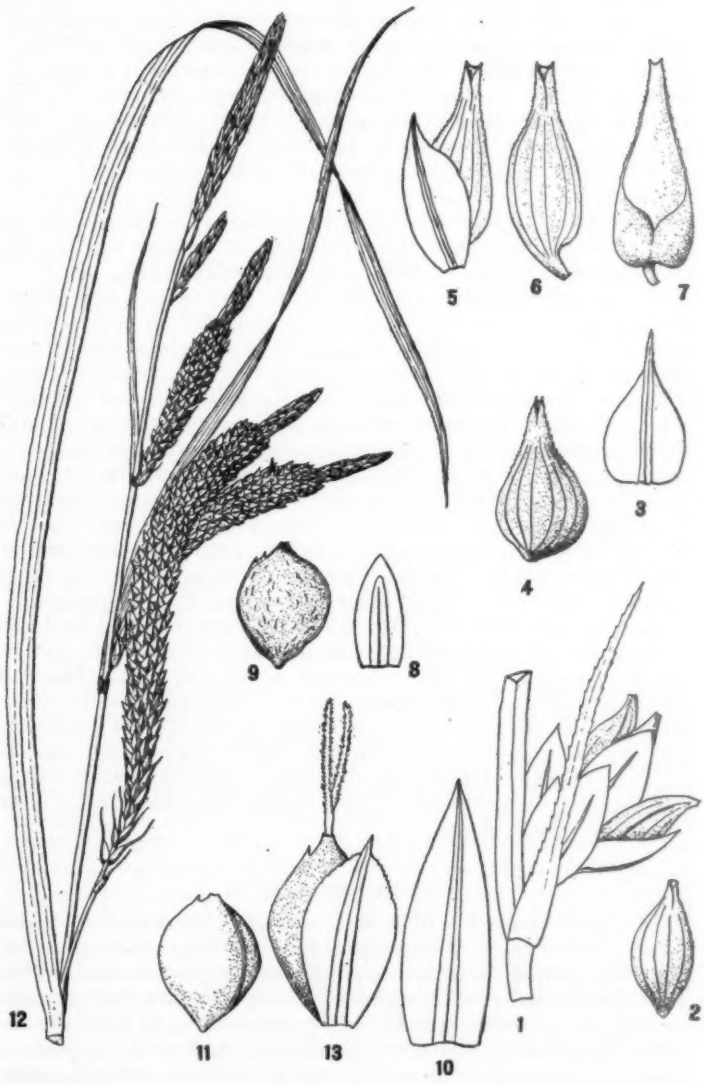
Carex chrysoleuca sp. n. (figs. 3–4).

Rhizome wanting, but apparently cæspitose, the leaf-sheaths fibrillose, light brown; leaves light green, about half as long as the culms, narrow, carinate, scabrous; culms from 40 to 55^{cm} in height, stiff, erect, trigonous, scabrous near the inflorescence, otherwise glabrous, phyllopodic; spikes about twenty, the lowest ones decompound, androgynous and the staminate portion very prominent, ovate, small in comparison to the size of the plant, sessile and contiguous, the bracts inconspicuous or the lowest one sometimes elongated, setiform; scales of staminate flowers lanceolate, sharply pointed, hyaline to light yellowish brown, those of the pistillate flowers (fig. 3) ovate with the midvein extended into a conspicuous awn, hyaline to yellowish, shorter than the perigynium; perigynium (fig. 4) sessile, erect or slightly spreading, broadly ovate, plano-convex, wingless, prominently several-nerved on convex face, light brown or greenish, scabrous along the distinct beak, which is deeply slit on the convex face; stigmata two.

Collected near Mariposa, California, by Mr. J. W. Congdon.

Carex vitrea sp. n. (figs. 5–7).

Rhizome wanting, but apparently cæspitose, the leaf-sheaths persisting, light brown; leaves glaucous, longer than the culms, narrow, flat, very scabrous; culms from 60 to 65^{cm} in height, slender, triangular, scabrous, phyllopodic; spikes numerous, decompound, forming an interrupted spicate inflorescence, up till 8^{cm} in length, androgynous, the staminate portion very prominent, sessile, the lower bracts setiform, short; scales of



Carex neurochlæna, figs. 1–2; *C. chrysoleuca*, figs. 3–4; *C. vitrea*, figs. 5–7; *C. dives*, figs. 8–9: *C. Schöttii*, figs. 10–11; *C. lacunarum*, figs. 12–13. (Explanation in text.) The figures 1–11 and 13 are magnified; fig. 12 represents the natural size.

staminate flowers lanceolate, mucronate, hyaline with green midvein, those of the pistillate flowers (fig. 5) ovate, acuminate and mucronate, hyaline, much shorter than the perigynium; perigynium stipitate, nearly erect, ovate-lanceolate, plano-convex, spongious at the base, wingless, several-nerved on the convex (figs. 5–6), nerveless on the plane face (fig. 7), light green to almost hyaline, scabrous along the narrow beak, which is emarginate and deeply slit on the convex face; stigmata two.

Collected at Palm Springs (Agua Caliente), desert base of San Jacinto Mountain, at an elevation of 500–700 ft., in Southern California, by Mr. S. B. Parish (No. 4144).

The last three species: *C. phæolepis*, *chrysoleuca* and *vitrea* are characteristic by the staminate portion of their spikes being very prominent, and by this character they are readily distinguished from all other members of the *Acanthophoræ*. However, there is a fourth species "*C. vallicola*" described by Dewey* which is said to exhibit the same peculiarity: "having the staminate part of the spikelet a short projecting column or cylinder at the apex, often longer than the pistillate part," and we thought at first that one of our species might be identical with this. But the perigynium of *C. vallicola* is described as "obovate, tapering below, rostrate and stiped, at the orifice oblique," besides "being nerveless," thus showing a marked distinction from the structure of the perigynia possessed by our species. Dewey's plant was collected in Jackson's Hole, on Snake River, at an elevation of 6000 ft., by Dr. F. V. Hayden, but the specimens which the writer has had the opportunity to examine, were so young and poorly represented, that they gave no illustration of the species whatever, and as we have learned from Mr. Clarke, there is no material of it in the Kew Herbarium. So far, *C. vallicola* stands as an imperfectly known species, but is evidently a near ally of those three, described above.

Carex venustula sp. n.

Rhizome matted with short stolons, the scale-like leaves brown, becoming fibrillose; basal leaves as long as the culm, narrow and flat, slightly scabrous, the cauline much shorter, but with long sheaths; culm about 42^{cm} in height, slender and weak, triangular, scabrous, aphyllopodic; spikes three to four, the terminal staminate, clavate, the lateral pistillate or the uppermost sometimes androgynous, contiguous, all borne on filiform peduncles, drooping, short and dense-flowered, subtended by sheathing bracts, of which the lowest one has a blade about as long

* This Journal, II, vol. xxxii, 1861, p. 40.

as the inflorescence; scale of staminate flower oblong, obtuse, reddish brown with green, not excurrent, midvein; scale of pistillate flower spathulate oblong, obtuse to aristate, deep purplish to almost black with the midvein obsolete, narrower than the perigynium; perigynium stipitate, erect, elliptical oblong, minutely granular above, two-nerved, pale green with purplish spots above, the beak short, emarginate; stigmata three or, sometimes, two, the style not exserted.

Alaska: Chistachina River, lat. 63, between Cook inlet and the Tanana River, collected by Captain E. F. Glenn, and British Columbia: Glacier, alt. 4122 ft., by Zoë W. Palmer.

Carex venustula is a near ally of *C. Montanensis* Bail., although it would not seem so if we compare the diagnoses alone. For it is hard to understand how specimens of authentically determined *C. Montanensis* can be described as belonging "to the Rigidæ, being allied to *C. Tolmiei*, yet having the habit of *C. Magellanica*." The diagnosis* is very incomplete and in several points incorrect. However, the main distinction between the two depends especially upon the structure of the scales and the perigynium: the former being about as long as the very broadly elliptical perigynium in *C. Montanensis*, while in the other species the scales, obtuse to aristate, are much shorter than the elliptical oblong perigynium. Common to both are the long-peduncled drooping spikes of dark color, the short stem-leaves and aphyllopodic culms.

Carex microchæta sp. n.

Rhizome stoloniferous with persisting, brownish scale-like leaves; leaves shorter than the culm, broad, flat and scabrous along the revolute margins; culm from 10 to 20^{cm} in height, erect, coarse and stiff, triangular, scabrous, phyllopodic; spikes three to four, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate, contiguous, erect, sessile, or the lowest one shortly peduncled, all short, thick and dense-flowered, subtended by sheathing bracts with the blades shorter than the inflorescence; scales of staminate and pistillate flowers, elliptical oblong, acuminate, purplish black with pale midvein extended into a short, scabrous awn, longer but narrower than the perigynium; perigynium stipitate, erect, elliptical, granular, two-nerved, purplish spotted above, whitish below, the beak short, bifid; stigmata three, the style exserted.

Yukon: Klondike, Indian Divide, collected by Professor John Macoun (No. 53,877).

The affinity is with *C. Tolmiei* and *C. spectabilis* of the *Melananthæ*.

* Botanical Gazette, 1892, p. 152.

Carex spectabilis Dew.*

This species, although well defined by Dewey (l. c.), has been overlooked by several authors and has been described as new "*C. invisa* Bailey," or confounded with various other species, for instance, with *C. macrochæta* Mey. var. *pseudopodocarpa* Kükthl., and *C. podocarpa* R. Br. We can add nothing to the diagnosis except that the culm is aphyllopodic, and that the scale-like leaves of the densely matted rhizome become fibrillose. It is said to have been originally collected in "the Arctic Region," but since then it has been found in several places in the mountains of British Columbia, Washington and California. In regard to *C. podocarpa* R. Br. we might state that Mr. C. B. Clarke has informed us that a careful examination of Robert Brown's specimen has convinced him that it is merely a young specimen of *C. rariflora* Sm.

Carex vulgaris Fr.

This plant offers an excellent example of a species distributed over a wide geographical area and possessed of great plasticity in respect to variation throughout the northern hemisphere. And so numerous are the varieties that Fries thought it would require a book to enumerate and describe them all; moreover, the variation is expressed in quite a distinct way wherever the plant occurs, in northern Europe or in the northwestern parts of this continent, where the species appears to be best represented. The species was already known to Tournefort and Ray as "*Cyperoides*" and "*Gramen*," while Linnæus was the first to describe it as a "Carex": *nigra verna vulgaris* (Flora Lapponica No. 330). Since then it has been described as *C. Goodenoughii* by Gay; a name, however, that only applies to the variety "*stolonifera*," while the typical form, as it occurs in Lapland, has received the name "*vulgaris*" by Elias Fries (Mant., III, p. 153). The plant is so well known and so well described that it is not necessary to reproduce the diagnosis *in toto* for the sake of illustrating the species as it occurs on this continent, but we might quote a few words about the structure of the perigynium. This organ is by Fries (l. c.) described as being subsessile, persisting, roundish-elliptical, many-nerved and longer than the obtuse scales; that the perigynium, sometimes, is nerveless, is evident from the description in Hartman's Flora of Scandinavia (11th edit.). If we now examine some of the most characteristic European varieties, Danish, Norwegian, Swedish and German specimens for instance, the perigynium appears with an outline of from roundish to very narrow elliptical, with a short stipe or strictly

* This Journal, vol. xxix, p. 248, 1836.

sessile, with the surface granular to densely verrucose, with or without a few spinulose projections along the upper margins, with the orifice of the short beak wholly glabrous or minutely spinulose, and finally with many very prominent nerves, with only a few and quite faint or apparently with none at all, the two marginal nerves being usually obsolete. Accompanying these perigynial structures a pronounced variation in habit occurs: in respect to the rhizome, the relative position of the pistillate spikes, the length of the peduncles, the length of the spikes, of the bracts, etc., distinctions that have proved to be sufficiently valid for establishing a number of varieties, especially in Northern Europe. Among these are, for instance, "*tornata* Fr.," which is densely cæspitose, with thick, rigid culms, broad leaves and heavy spikes, "*juncea* Fr.," a very slender form with convolute, filiform leaves and remote spikes, "*stolonifera* (Hoppe)" with long stolons and short, curved culms, "*longe pedunculata* Blytt" with the culms, tall, nodding at the apex and with long-peduncled, dark spikes of which the scales are acute and longer than the perigynia, "*rigida* Blytt" which grows in dense tufts and of which the culms and leaves are very stiff and scabrous, besides the pistillate spikes are very long, linear and often androgynous, "*atra* Blytt" with slender culms, and black, sessile spikes, mostly in a dense head, and "*anomala* Blytt" with the terminal spike gynæcandrous. By studying the species as it is represented in this country, we have seen the typical *C. vulgaris* from Alaska, Colorado, Cape Breton Island and Nantucket, Massachusetts, while the var. *stolonifera* has been collected in Labrador. It appears, however, as if the species is best represented in the northwestern parts of this continent — Alaska and Yukon, where certain varieties have been collected in large quantities and at several stations. Of these we propose as new

var. *limnophila* nob.

Rhizome densely cæspitose; culms curved, only about 10^{cm} in length; spikes very short and thick, sessile and contiguous, almost capitate, the terminal mostly gynæcandrous; perigynium stipitate, elliptical, denticulate near the beak, purplish spotted above.

Collected on St. Paul Island, Bering Sea, growing in mud by marshes. Mr. James M. Macoun (No. 16,613); also on a nunatak in Columbia glacier, Prince William's Sound, by Messrs. Coville and Kearney (No. 1365).

This variety bears a strong resemblance to *C. rufina* Drej., from which it differs only in its more robust habit and the

structure of the perigynium. However, it is interesting to see that some Scandinavian authors are inclined to consider *C. rufina* as a reduced form of *C. vulgaris.*

var. *hydrophila* nob.

Rhizome very slender, stoloniferous, the scale-like leaves persisting, shining, purplish brown; leaves about as long as the very slender culms, narrow but flat; spikes cylindrical, dense-flowered, peduncled, erect or somewhat spreading; perigynium prominently stipitate, roundish-elliptical, wholly glabrous and nerveless.

Yukon: in water, Colorado Creek, collected by Professor John Macoun (No 53,843).

var. *lipocarpa* nob.

Rhizome densely cæspitose with persisting, light brown sheaths; leaves glaucous, narrow but flat as long as the culms; culms from 15 to 40^{cm} in height, slender, but erect; spikes long and very dense-flowered except towards the base, more or less peduncled, especially the lowest one, which is often developed from near the base of the culm and branched; bracts foliaceous and quite long; perigynium with a long stipe, elliptical, glabrous, many-nerved, the beak very distinct and proportionately long.

Collected in Alaska at several stations, on Vancouver Island, in the Selkirk Mountains, British Columbia, and in the Chilliwack Valley, by Mr. James M. Macoun and others.

The fact that the perigynium is early deciduous in this variety has led several authors to the belief that it is identical with the South American *C. decidua* Boott, but the terminal spike is, in this species, nearly always gynæcandrous and the perigynium is oblong-ovate, denticulate-serrate.

Some of the specimens from Alaska were sent to Mr. C. B. Clarke of Kew, who kindly informed the writer that these were identical with Scouler's Columbia River plant, which Boott first named *C. decidua*, but afterwards corrected to *C. vulgaris* Fr.

The so-called *C. interrupta* Bcklr. var. *impressa* Bailey is, also, according to Mr. Clarke, a form of *C. vulgaris*, and almost like the typical plant.

var. *elatior* Lang.

Rhizome cæspitose; culms and leaves until 55^{cm} in length, very slender; spikes sessile, cylindrical and dense-flowered, some

what remote, subtended by short, filiform bracts; perigynium elliptical, stipitate, many-nerved, glabrous.

Nova Scotia: Halifax, collected by Professor John Macoun (No. 16,678). The specimens were identified as var. *strictæformis* Bail., but they do not differ in any way from our European material, although the nerves of the perigynium are not always as prominent as in the American plant.

In comparing these North American varieties of *Carex vulgaris* with the European, we notice as a prominent feature for distinguishing these the strong development of the stipe in the former, and sometimes to such an extent as making the perigynia early deciduous. In the European forms the stipe is often very distinct, but seldom as long and slender as in the American. In regard to the nervation, the perigynium shows, as already stated, several variations, and a prominently many-nerved perigynium seems to be the most frequent among the representatives in this country.

The beak is, as a rule, very short in all European specimens, also in the American with the exception of the var. *lipocarpa*, where it is quite prominent.

There is, still, another plant which may belong here, but of which the writer has only studied a scant supply of material. This is *C. Kelloggii* W. Boott, which seems very near the typical *C. vulgaris*, by the very short beak and stipe of the perigynium.

Carex sphacelata sp. n.

Rhizome ascending, stoloniferous with persisting, deep reddish brown scale-like leaves; leaves about as long as the culm, rather broad and flat, glabrous; culm from 30 to 40^{cm} in height, erect, stiff, triangular, glabrous, phyllopodic; spikes three to five, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate, contiguous or the lower ones remote, sessile or short-peduncled, erect, dense-flowered, subtended by foliaceous, sheathless bracts with the blades broad and longer than the inflorescence; scale of staminate flower linear-lanceolate, obtuse, deep brown with pale midrib; scale of pistillate flower ovate-lanceolate, almost black with the midvein obsolete, shorter and much narrower than the perigynium; perigynium stipitate, erect, broadly elliptical, granular, two-nerved, purplish-spotted above, whitish below, the beak short, entire; stigmata two, the style enclosed.

Collected in Yukon: Colorado Creek, by Professor John Macoun (No. 53,847).

This species may be placed near *C. aquatilis* Wahl.

Carex chionophila sp. n.

Rhizome cæspitose with persisting, brown leaf-sheaths; leaves longer than the culm, narrow but flat, scabrous; culm from 30 to 40^{cm} in height, erect, slender, trigonous, scabrous, phyllopodic; spikes four to five, the terminal staminate, the lateral pistillate or with a few staminate flowers at the apex, contiguous, sessile or the lowest one peduncled, erect, dense-flowered, cylindric and until 4^{cm} in length, subtended by sheathless bracts with blades about as long as the inflorescence; scale of staminate flower oblong, obtuse, purplish with pale midvein; scale of pistillate flower ovate-oblong, obtuse, black with pale midvein, shorter and much narrower than the perigynium; perigynium minutely stipitate, erect, pyriform, granular above, nerveless, light green above, whitish below, the beak very short, entire; stigmata two or three.

Collected in a brook, West Dawson, Yukon, by Professor John Macoun (No. 53,849).

Allied to *C. sphacelata* but is readily distinguished by the characters enumerated above; it is altogether a more graceful plant with slender culms and narrower leaves, besides of a much lighter color.

Carex consimilis sp. n.

Rhizome horizontal, stoloniferous with persisting light brown scale-like leaves; leaves about as long as the culm, narrow with revolute margins, scabrous; culm about 25^{cm} in height, erect, stiff, triangular and scabrous, phyllopodic; spikes four, the terminal staminate, the lateral pistillate or sometimes androgynous, contiguous, sessile or the lowest one short-peduncled, erect, subtended by very short, sheathless bracts; scale of staminate flower linear-lanceolate, light brown; scale of pistillate flower ovate-lanceolate, acute to obtuse, black with the midvein obsolete, longer, but narrower than the perigynium; perigynium minutely stipitate, erect, orbicular, granular above and sharply denticulate along the upper margins, two-nerved, purplish spotted above, light brownish green below, the beak short, entire; stigmata two, style short but exserted.

Collected near Klondike, Indian Divide, Yukon, by Professor John Macoun (No. 53,878).

In habit not unlike *C. hyperborea* Drej., but the perigynium is very different.

Carex cyclocarpa sp. n.

Rhizome stoloniferous with persisting, purplish scale-like leaves; leaves shorter than the culm, flat, but narrow; culms from 12 to 42^{cm} in height, slender, but erect, or slightly curved,

triangular, scabrous, phyllopodic; spikes three to four, the terminal staminate, the lateral pistillate or, sometimes, the upper one androgynous, contiguous, sessile or the lowest one peduncled, erect, dense-flowered, short, subtended by bracts, of which only the lowermost is foliaceous, shorter than the spike and with black auricles; scale of staminate flower linear-lanceolate, brown with pale midvein; scale of pistillate flower ovate, obtuse, black with the midvein obsolete, shorter and much narrower than the perigynium; perigynium shortly stipitate, erect, turgid, nearly globose, granular, two-nerved, brownish green with purplish spots above, the beak minute, entire; stigmata two or three, the style exserted.

Grows in tufts in woods and in boggy places: West Dawson, mountains back of Dawson, Hunker Creek, Yukon, collected by Professor John Macoun (Nos. 53,842, 53, 55, and 58). This together with the preceding, *C. consimilis*, are no doubt close allies, but they appear so distinct from the other *Microrhynchæ*, that their place within the section seems uncertain. In some respects they resemble *C. vulgaris* and *C. rigida*, in others *C. cæspitosa* and *C. lugens*, yet they may "ad interim" be placed with *C. nudata* between *C. aquatilis* and *C. interrupta*, as indicated in "Greges Caricum."

Carex limnocharis sp. n.

Rhizome stoloniferous with persisting, purplish scale-like leaves; leaves as long as the culm, rather narrow, flat, scabrous; culm 30^{cm} in height, erect, but curved at the apex, triangular, glabrous, phyllopodic; spikes five, the terminal staminate, the lateral pistillate or the uppermost androgynous, contiguous, peduncled, spreading, not very dense-flowered, about 5^{cm} in length, but thin, subtended by sheathless, foliaceous bracts, much longer than the inflorescence; scale of staminate flower linear-lanceolate, acute, light brown; scale of pistillate flower ovate acuminate, reddish brown with green, not excurrent midrib, narrower but longer than the perigynium; perigynium stipitate, erect, broadly elliptical, granular above, nerveless, pale green, the beak short, entire; stigmata two, style enclosed.

In muddy places, Klondike River, Yukon, collected by Professor John Macoun (53,846).

Allied to *C. acutina*, but more robust; a beautiful species with long, slender spikes of reddish brown color, in habit much like the European *C. prolixa* Fr.

Carex millegrana sp. n.

Rhizome wanting, but apparently cæspitose with persisting reddish-brown leaf-sheaths: leaves shorter than the culm, nar-

row, but flat, scabrous; culms until 60cm in height, slender, triangular, scabrous, phyllopodic; spikes five to six, the terminal staminate, the lateral pistillate or the uppermost androgynous, contiguous, nearly sessile, spreading to almost drooping, from 4 to 8cm in length, slender, but very dense-flowered except towards the base, subtended by sheathless bracts with very short blades, the lowest barely half as long as the inflorescence; scale of staminate flower elliptical oblong, pale reddish-brown with green midvein; scale of pistillate flower elliptical, a little darker, spreading and somewhat shorter than the perigynium; perigynium sessile, elliptical, granular, compressed, prominently two-nerved (the lateral), pale greenish brown, the beak short, emarginate: stigmata two.

South Dakota; Rosebud Creek, collected by Mr. E. J. Wallace.

In general habit much like *C. angustata*, but we prefer, nevertheless, to place it near *C. lenticularis*.

Carex dives sp. n. (figs. 8–9).

Rhizome wanting, apparently cæspitose, lower leaf-sheaths light-brown, not fibrillose; leaves as long as the culm, quite broad and flat, scabrous along the margins; culms up till 60cm in height, erect, stiff, triangular, very scabrous, phyllopodic; spikes from six to seven, the terminal and uppermost one or two lateral staminate, the others pistillate, more or less remote and peduncled, especially the lowest one, nodding, very dense-flowered, from 4 to 10cm in length, subtended by sheathless, foliaceous bracts of which the lower ones reach high above the inflorescence; scale of staminate flower linear-oblong, mucronate, pale brown with green midvein; scale of pistillate flower (fig. 8) lanceolate oblong, acute, purplish with green midvein, much narrower, but about as long as the perigynium; perigynium (fig. 9) minutely stipitate to sessile, erect, roundish, compressed, granular, two-nerved, sparingly denticulate along the upper margins, pale green with scattered purplish spots and streaks, the beak very short, entire; stigmata two.

Collected in Oregon by Mr. L. F. Henderson; in California: "in open swamps with *C. utriculata*, 12 mile house San Jose R. R." collected by H. N. Bolander, and in Chilliwack Valley, British Columbia, by Mr. James M. Macoun.

The affinity is with *C. Sitchensis* Prescott.

Carex salina Wahl.

The statement that "this species does not occur on the western side of this continent"* is a mistake, since it has been

* Memoirs Torrey Bot. Club, i, 45, 1889.

collected at several stations on the Alaskan coast, sometimes associated with its near ally, *C. subspathacea* Wormskj.

Carex hæmatolepis Drej.

Described by Drejer* as follows: "Spica mascula 1, femin. 3–5 elongatis cylindraceis laxifloris in pedunculo lævi valido erectiusculis v. demum nutantibus, squamis ovatis acutis serrulato-mucronulatis perigynia ovali-ovata substipitata subsuperantibus, stigmatibus 2–3". "Squamæ ♀ atro-sanguineæ tenuissime punctulatæ nervo tenuissimo discolore, ovatæ, acutæ serrulato-aristatæ v. muticæ, perigynia fere tegentes et superantes. Perigynia obsolete nervata decolora stramineo-viridia, rostro brevissimo integro." Only known from Greenland, but may be found on the northeastern coasts of this continent. It shows some resemblance to *C. cryptocarpa*, but differs from this by the nearly erect pistillate spikes, the mucronate scales and the much narrower perigynia.

Carex cryptocarpa C. A. Mey.

To American botanists this species is so well known and well understood that it should hardly be necessary to make any further mention of it as a little known species. However in a recently published paper dealing with Arctic *Carices*,† the species is enumerated as identical with *C. Lyngbyei* Hornem., with *C. filipendula* Drej. and with *C. capillipes* Drej. and has received the new name *C. Lyngbyei* Hornem., this being older than the name of Meyer. If now the diagnosis of these four formerly recognized species had been drawn up so as to demonstrate their identity, we should have no objection to make, but it seems to us that a comparison of the plants themselves and the original diagnoses makes it rather unnatural to combine them as only one, a fact that becomes more evident when we examine the renewed description of *C. Lyngbyei* (l. c.).

Habitually these four species are somewhat like each other, but *C. cryptocarpa* is readily distinguished by being very robust with broad leaves and heavy spikes, while the others, especially *C. Lyngbyei*, is exceedingly slender in all its parts. The specific characters are, however, to be drawn from the structure of the scales of the pistillate spike and of the perigynium, and we have noticed the following distinctions: The scale is in *C. cryptocarpa:* oblong to oblong-lanceolate, acute with a broad midvein; in *C. Lyngbyei:* lanceolate with the midvein extended into a very long, serrulate awn; in *C. fili-*

* Revisio critica Caricum borealium (Naturhist. Tidsskr. Kjöbenhavn 1841).
† Ostenfeld, C. H., Flora Arctica, Copenhagen, 1902, p. 75.

pendula: ovate, acute to aristulate; in *C. capillipes:* ovate-lanceolate, mucronate. The perigynium is in *C. cryptocarpa:* broadly elliptical, minutely scabrous along the upper margins, and with the veins hardly visible; in *C. Lyngbyei:* obovate, glabrous, prominently veined; in *C. filipendula:* oval to obovate, glabrous, obsoletely veined; in *C. capillipes:* subovate, scabrous along the upper margins, obsoletely veined. In Flora Arctica the description of these four species "*C. Lyngbyei*" reads thus: "scales three-nerved, acuminate with elongated midvein longer than the faintly nerved utricles." In the hundreds of specimens which we have examined of the Alaskan *C. cryptocarpa*, we have invariably found the scales simply acute, and we failed to observe any deviation from the description of the perigynium. In regard to *C. filipendula*, of which we have examined material from Greenland and Iceland, we cannot but express our doubt as to the identity of this with *C. cryptocarpa*, and we are indeed much more inclined to consider it as a nearer ally of *C. salina*, an opinion that has already been pronounced by such critical students of the genus as Blytt and Boott. *C. Lyngbyei* is too characteristic a species to be confounded with any of the others and appears, thus, to be the only endemic species of the Færœ islands; and finally in regard to *C. capillipes* this is yet imperfectly known, but as long as some distinctive characters have been noted, especially in the perigynium, it would be safer to keep it as a distinct species until it is again studied and better known.*

Carex macrochæta **C. A. Mey.**

Although being exceedingly frequent on the Alaskan coast and the islands, the species shows but slight variation. The terminal spike is usually wholly staminate, but we found, however, a few specimens from Unalaska in which this was either androgynous or gynæcandrous or even entirely pistillate. Two quite striking varieties were noticed, viz:

var. *emarginata* **nob.**

Taller and more slender than the typical plant; spikes very long, loose-flowered, remote; scales of pistillate spike prominently emarginate with a seta four times as long as the body of the scale.

Alaska: Kukak Bay, collected by Messrs. Coville and Kearney.

*To give the reader some further idea of the treatment of the *Carices* in Flora Arctica, we might quote, for instance, the synonymy given of *Carex rotundata:* "*ambusta*," "*compacta*," "*membranacea*" and "*vesicaria γ alpigena*." Such errors are the inevitable result of compilation without access to authentic material and to the most important literature, the works of Boott for instance. It is, indeed, a pity to see the interesting Arctic plants submitted to so poor a treatment.

var. *macrochlæna* nob.

Very robust with four short and heavy pistillate spikes; perigynium very large and longer than the simply mucronate scale.

St. Paul Island, Bering Sea, collected by Mr. James M. Macoun.

Carex nesophila sp. n.

Rhizome stoloniferous with light brown, fibrillose, scale-like leaves; leaves shorter than the culm, relatively broad and flat, glabrous; culm very variable in height from 12 to 38^{cm}, erect, slightly bent near the apex, glabrous, phyllopodic; spikes from two to four,* the terminal staminate, the lateral pistillate or very seldom androgynous, contiguous, sessile and erect or the lowermost borne on exserted peduncles and, sometimes, nodding, all subtended by sheathless bracts with blades about as long as the inflorescence or shorter; scale of staminate flower elliptical, acute, deep purplish with three green midveins; scale of pistillate flower broadly elliptical, acute, purplish to almost black with faintly visible midrib of three veins; perigynium a little longer, but narrower than the scale, sessile, erect, from oval to elliptical oblong, few-nerved, pale green, the beak purplish, very short, entire or obliquely cut; stigmata three or, sometimes, two, the style not exserted.

St. Paul Island, Bering Sea: abundant on uplands with *Sieversia Rossii*, *Artemisia globularis* and *Potentilla villosa*, but not associated with any species of *Carex*, collected by Mr. James M. Macoun (Nos. 16,614 and 16); also on Popoff Island, Shumagin Islands, by Mr. T. Kincaid.

Carex nesophila resembles sometimes certain forms of *C. salina*, but the structure of the perigynium is always more like that of *C. macrochæta*, besides the spikes being contiguous. Although being a rather inconspicuous plant it has been collected in great numbers and only on the islands in Bering Sea, hence the name "*nesophila*."

Carex Schottii Dew. (figs. 10–11).

The species was originally founded on immature specimens from Santa Barbara, California, some of which are in the herbarium at Kew; Mr. Clarke has examined these and informed us that Bolander's specimens No. 1570, collected in swamps at Oakland and in salt-marshes near Fort Point, San Francisco, are identical with these; also identical with Bolander's plant

* As to the number of spikes we find in twenty-two specimens:
15 specimens with 3 lateral spikes.
5 " " 1 " "
2 " " 2 " "

is the so-called *C. obnupta* Bail., of which Mr. J. W. Congdon has sent us very fine material collected in swamps, Mendocino County, and they all answer the diagnosis of *C. Schottii* very well, but seem distinct from the little that we know of Dewey's *C. Barbaræ*. (Fig. 10 = scale of pistillate spike; fig. 11 = perigynium, both of *C. Schottii*.)

Carex magnifica Dew.

Through the kindness of Mr. Clarke we have learned that most of the specimens of so-called *C. Sitchensis* belong to this unpublished species of Dewey, who sent it to Boott. The real *C. Sitchensis* is a very different plant with slender and remote pistillate spikes, of which we have studied authentic material in the herbarium of Bischoff, which is now in the possession of the St. Louis botanical garden. This species, *C. Sitchensis* Prescott, is known from the coasts of Alaska and Oregon, and has been described as *C. Howellii* Bail.

Mr. Clarke, furthermore, states that Boott's plate 594 (*C. laciniata*), as to the plant depicted, represents *C. Sitchensis* Presc. *vera*, while the details are taken from the old, true *C. laciniata*. Identical with *C. Sitchensis* Presc. are, also, *C. cryptocarpa* Franch. and *C. atrata* Hook et Arn.

Carex lacunarum sp. n. (figs. 12–13).

Roots thick, very hairy; rhizome cæspitose with persisting, reddish brown leaf-sheaths; leaves as long as the culm, relatively narrow, carinate, glaucous and very scabrous; culm about 60^{cm} in height, coarse, triangular, scabrous, phyllopodic; spikes three to five,* the terminal and uppermost lateral staminate, the others pistillate or androgynous, more or less contiguous, sessile or the lower ones peduncled, nodding, cylindric, very dense-flowered, from 2 to 8^{cm} in length, subtended by bracts with blades longer than the inflorescence (fig. 12), sheathless or the lowest one with a short sheath; scale of staminate flower lanceolate, erosely denticulate above, three-nerved, pale purplish with hyaline margins and base: scale of pistillate flower (fig. 13) broadly ovate, acuminate, mucronate to aristate, erosely denticulate above, three-nerved, purplish brown with hyaline margins; perigynium (fig. 13) longer than the body of the scale, sessile or nearly so, erect, rhombic-oval, biconvex, coriaceous, two-nerved, slightly denticulate along the upper margins, otherwise glabrous, pale brown, the beak short, entire; stigmata two.

* As to the number of spikes, staminate and pistillate, we notice in:

7	specimens	2	staminate	spikes.	
2	"	1	"	"	
4	"	3	pistillate	"	
5	"	2	"	"	

California: Lagoon at Sebastopol, Sonoma County, collected by Mr. A. A. Heller (No. 5797), and in a marsh at Berkeley, collected by Mr. J. Burtt Davy. The species is nearest related to *C. magnifica* Dew., but is readily distinguished by the lighter color of the spikes and the very dense and regular arrangement of the pistillate flowers.

Carex siderosticta Hance.

We have placed this as a member of the *Lejochlænæ*, and it is interesting to see that in addition to the shape of the perigynium, the species agrees, also, by its monopodial rhizome and long-sheathed bracts, with the central forms: *C. laxiflora*, *Careyana*, etc. Otherwise the lateral spikes are all androgynous, a character which we do not think is sufficient for the segregation of the species from the *Carices genuinæ*.

It is somewhat remarkable that the rhizome is rather slender, creeping and stoloniferous, while most of the monopodial *Carices* have a short, cæspitose rhizome.

Carex cryptostachys Brongt.

As already stated by Boott, this must be referred to the *Dactylostachyæ*, and it possesses the same monopodial rhizome as is observable in *C. digitata* for instance; the structure of the perigynium is much the same, but the ramified culms with quite numerous, androgynous spikes, makes the species appear as the most evolute type of the section.

Carex physochlæna sp. n.

Rhizome loosely cæspitose with persisting purplish leaf-sheaths; leaves much shorter than the culm, very narrow, but flat, scabrous; culms from 30 to 42^{cm} in height, erect, slender, but stiff, trigonous, scabrous, only leafy at the base, phyllopodic; spikes two to three, the terminal staminate, the lateral pistillate, mostly contiguous, sessile, erect, very thick and dense-flowered, subtended by short, filiform, sheathless bracts, the lowest one spreading and about as long as the spike; scale of staminate flower obovate-oblong, obtuse, purplish with green midvein and pale margins; scale of pistillate flower ovate, obtuse, deep purplish to almost black with the midvein obsolete, shorter than the perigynium; perigynium sessile, spreading, oval to oblong, inflated, glabrous, faintly nerved, purplish above, yellowish below, the beak short, bidentate; stigmata three, the style flexuose within the perigynium.

Collected on Coal Creek hill, near the Yukon River, by Mr. Fr. Funston (No. 139).

Very distinct by the heavy, dark spikes contrasting the slender culm and narrow leaves: its nearest ally is *C. physocarpa*.

Brookland, D. C., October, 1903.

ART. XXVIII.—*Characters of Pteranodon (Second Paper)*; by G. F. EATON. (With Plates XIX and XX.)

BRIEF notices of some of the characters of *Pteranodon* Marsh were published in this Journal in July, 1903. A restoration of *Pteranodon longiceps* is now about to be installed at St. Louis, which has been prepared under my direction as the contribution of the Department of Vertebrate Paleontology of the Yale Museum to the University's exhibit at the Louisiana Purchase Exposition. It is therefore advisable to describe such additional characters of *Pteranodon* as are manifest in the restoration.

A half-tone engraving of this restoration appears as Plate XIX.

The Sclerotic Circle.

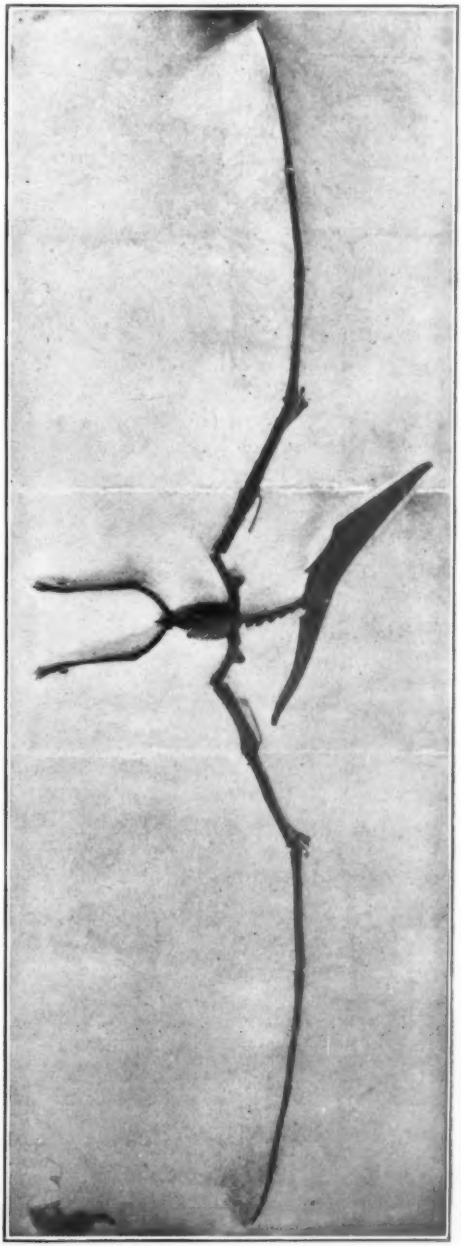
The sclerotic circle is composed of twelve thin plates of bone arranged with overlapping edges, so as to form a hollow truncate cone similar in shape to the avian sclerotic circle. Plate XX, figure 1, shows the arrangement of these plates in the left orbit of a large head of *Pteranodon*. By removing the matrix from under the left side of the skull, which was crushed laterally, the circle was exposed pressed inward against the interorbital septum and with the component plates little disturbed from their normal position.

Professor Williston* refers to the sclerotic circle of the allied genus *Nyctosaurus (Nyctodactylus)* in these words: "It had a ring of thin, large sclerotic plates, which were preserved in displaced positions. The separate plates were not united by imbrication, as in the mosasaurs." The chapter on the Pterosauria in the new edition of Zittel's Paleontology, 1902, as revised by Professor Williston, contains no description of this structure in either *Pteranodon* or *Nyctosaurus*. Oddly enough, in this revision, it is *Pteranodon* that is credited with a sclerotic circle, and not *Nyctosaurus* in which Professor Williston observed the structure.

The Vertebræ.

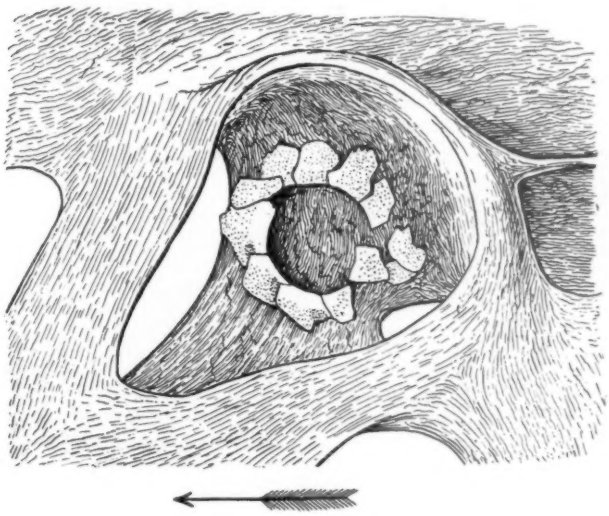
The most important note to be made here concerns the vertebral formula, which I have now determined. I have figured and described in this Journal (July, 1903) the series of vertebræ which are anchylosed together to support the ilia. Further investigation has shown the number of presacrals attributed to *Pteranodon* by previous writers to be incorrect. Instead of eight cervicals, as given by Professor Williston, there are in reality nine. In the dorsal series are included

*Journal of Geology, vol. x, p. 528, 1902.



Restoration of PTERANODON LONGICEPS Marsh.
One twenty-fourth natural size.

1



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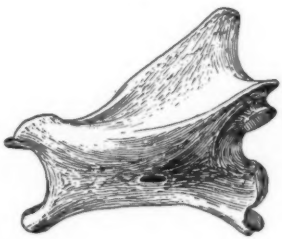

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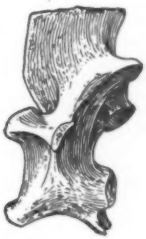


4

5

6

7

8

PTERANODON Marsh.

eight vertebræ anchylosed to form the notarium, and four free dorsals intervening between the notarium and the sacrum.

Professor Williston has been at considerable pains to demonstrate the number of cervical vertebræ in *Pteranodon* and *Nyctosaurus*, and it is from him I quote:* "If, however, we consider that vertebra which bears the first rib articulating with the sternum to be the first dorsal, then I believe that the prevailing number of cervicals in pterodactyls is eight.

. . . . . .

"From the foregoing, then, it seems assured that there is a free, short vertebra in front of the notarium, in both *Pteranodon* and *Nyctosaurus*, bearing a free, small rib, which does not unite with the sternum. This vertebra is the eighth cervical, and is probably present in all pterodactyls."

Following the atlas and axis are five vertebræ with long centra, then two vertebræ with short centra, making nine cervicals in all. Plate XX, figures 2, 3, and 4, show the seventh, eighth, and ninth vertebræ in their correct sequence, the longest of the three being the seventh. As there is no doubt that the seventh is the most posterior of the long-bodied cervicals, it is here only necessary to illustrate and call attention to the last three cervicals, and to state that they were preserved in their normal arrangement and that the ninth was in contact with the first true dorsal or notarial vertebra, i. e., the first vertebra connected by ribs with the sternum. I hope to show later that Professor Williston is right in supposing that *Pteranodon* and *Nyctosaurus* have the same cervical formula. The number of cervicals in *Pteranodon*, however, is nine, and not eight as formerly supposed. Fortunately, the material in the Yale University Museum satisfactorily decides this mooted question.

In describing the specimen of *Nyctosaurus* upon which Professor Williston bases his calculation of cervical vertebræ (Osteology of Nyctosaurus), he says that the eighth cervical lay "close to the first notarial vertebra, and near the presternal process of the sacrum," from which statement I must suppose his evidence less satisfactory than my own.

The four free dorsals which follow the notarium are shown in their normal sequence in figures 5, 6, 7, and 8, of Plate XX. Unlike the eight notarial vertebræ, these four were probably capable of slight motion. This is indicated by the character of the articular facets of the zygapophyses and of the ends of the centra. The figures correctly show transverse processes terminating in facets for the support of single-headed ribs. Like all the vertebræ in the entire vertebral column, so far as observed, these four free dorsals are procœlous.

* On the Osteology of Nyctosaurus, Field Columbian Museum, Publication 78, pp. 127, 129, June 1, 1903.

By assuming that the first four vertebræ of the sacral series (in the broader sense) are homologues of the lumbars of other groups, the total number of presacral vertebræ would appear to be twenty-five. This compares closely with the supposed number of presacrals in the Eusuchia.

Paleontological Laboratory,
Yale University Museum, February 29, 1904.

EXPLANATION OF PLATES.

PLATE XIX.

FIGURE 1.—Restoration of *Pteranodon longiceps* Marsh; prepared from the original fossil bones, by H. Gibb, under the direction of G. F. Eaton, at the Yale University Museum, March, 1904. One twenty-fourth natural size.

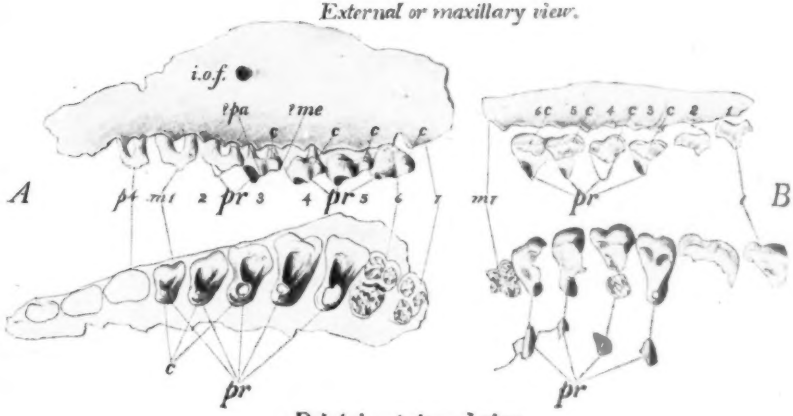
PLATE XX.

FIGURE 1.—Left orbit and sclerotic circle of *Pteranodon*. The arrow points to the anterior extremity of the head.
FIGURE 2.—Seventh cervical vertebra of *Pteranodon*.
FIGURE 3.—Eighth cervical vertebra of *Pteranodon*.
FIGURE 4.—Ninth cervical vertebra of *Pteranodon*.
FIGURE 5.—Ninth dorsal vertebra of *Pteranodon*.
FIGURE 6.—Tenth dorsal vertebra of *Pteranodon*.
FIGURE 7.—Eleventh dorsal vertebra of *Pteranodon*.
FIGURE 8.—Twelfth dorsal vertebra of *Pteranodon*.

All the figures are three-fourths natural size, and illustrate the left side of the specimens.

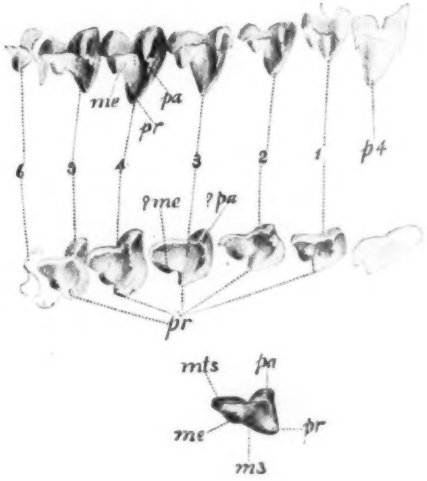
1

External or maxillary view.



Palatal or internal view.

2



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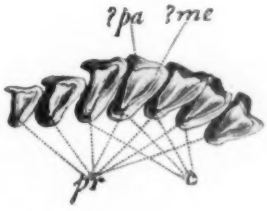

ART. XXIX. — *Palæontological Evidence for the Original Tritubercular Theory;* by HENRY F. OSBORN. (With Plate XXI.)

THERE has been a strong reaction of late against the original tritubercular theory so far as it concerns the origin of the upper molar teeth of mammals, by embryologists, comparative anatomists and palæontologists. Among the latter, Dr. J. L. Wortman has reached especially strong conclusions, which have been published in this Journal.*

According to the original theory of Cope as developed by Osborn, the homologue of the main reptilian cone or protocone is invariably situated on the antero-internal, or lingual side in the upper teeth.

According to the views of the earlier opponents of the tritubercular theory, the protocone is found on the antero-external side, as in the premolars, and corresponds with the cusps which Osborn called the paracone. According to the views of M. F. Woodward,† which were based on embryology, the protocone varies in position in different groups of mammals, namely, antero-internal in certain zalambdodont insectivores (Centetes), and antero-external in Dilambdodonta (Erinaceus), as well as in most other mammals. Similarly Wortman, by analogy with the premolars (this Journal, November, 1903), believes that the position of the protocone may have been variable, that is, in some cases internal, in others external.

The whole point of this very complex question turns on the simple question of evidence whether the main reptilian cone, or *protocone*, of the ancestors of mammals was found upon the antero-internal side or on the antero-external side of the upper molars.

The original evidence upon which Osborn supported and developed Cope's theory is that derived from the rare upper molar teeth of the Jurassic mammals. Osborn‡ cited (1) the upper teeth of *Triconodon*, in which the main cone is *central*, (2) the upper teeth of *Peralestes* (British Museum) fig. 2, in which the main cone is *internal*, (3) the upper teeth of *Kur-*

* "In view of the facts above set forth, however, I am more firmly than ever of the opinion, that all such attempts [to name the cusps of the molars in accordance with their supposed homologies, rather than with their relative positions] are foredoomed to failure, and I believe they should be abandoned as utterly useless and confusing; that of Professor Osborn, being doubly erroneous, is therefore the most open to objection in this regard." (This Journal, vol. xvi, November, 1903, p. 368.)

† Proc. Zool. Soc., Lond., 1896, pp. 557–594.

‡ On the Structure and Classification of the Mesozoic Mammalia. Jour. Acad. Nat. Sci., Phila. (2), ix, pp. 242–246.

todon, fig. 3, in the British Museum in which the main cone is *internal*, (4) a reference by Professor Marsh to the fact that in the upper molars of *Dryolestes* the main cone is *internal*. In each case the main cone was believed to be the protocone.

The teeth last mentioned (4) were not personally examined at the time, but through the kindness of the late Professor Charles E. Beecher I was recently enabled to study them in the Yale University Museum.

The specimens consist of two superior series. They both show that the large, single, main cusp of the crown is *internal*, and in my opinion they present *conclusive evidence of the truth of the tritubercular theory as originally proposed.*

More in detail, the two specimens taken together show perfectly the structure of both the crowns and fangs of seven superior molar teeth, and confirm entirely the general description given by Marsh, to which some important points may be added as follows:

(1) The molars are sharply distinguished from the premolars, which are bifanged teeth with simple, laterally compressed crowns. (2) The molar crowns are broadly transverse or triangular, and upon the *internal* side of each is a large, conical, pointed cusp, *pr*, supported by a large, stout fang, fig. 1 A, *m6*, *m7;* around the inner side of each of these cusps is a delicate cingulum, fig. 1 A, *c*. (3) The *external* portion of the broadly triangular crown is supported on two smaller fangs, fig. 1 A, *m6*, *m7*. (4) The external portion of the crown is depressed, and bears one large antero-external cusp *?pa* and one smaller postero-external cusp *?me* which is either partly worn away or less pronounced in development. (5) Outside of this external wall there is also a faint basal cingulum, *c*, *c*, *c*. (6) Connecting these low external cusps with the elevated internal cusp are two transverse ridges; the anterior transverse ridge is higher and stronger than the posterior.

These features are clearly shown in the accompanying drawings, fig. 1, which were made and shaded under the camera lucida and therefore admit of no doubt as to interpretation.

These two specimens fully supplement and confirm each other; they also supplement the evidence derived from the study of the superior molar teeth of *Peralestes* (fig. 2) and of *Kurtodon* (fig. 3) in the British Museum, which were cited and figured in my memoir and in various subsequent papers on trituberculy.

Again summing up this combined evidence, we find in the Jurassic period the superior molars of the only mammals known (excepting the Triconodonta and Multituberculata) to consist of a large conical internal cusp or *protocone*, which we

have every reason to believe is homologous with the large external cusp or *protoconid* in the lower jaw.

Secondly, that the external cusps in the superior molars are depressed and comparatively small, consisting of two, more or less well-defined cusps. Thirdly, that this palæontological evidence lends no support, either in crown or fang structure, to the evidence of embryology that the paracone (*?pa*, or antero-external cusp) is the oldest cusp. Fourthly, that it lends no support to the premolar-analogy theory, which was originally suggested by Huxley* in his description of the teeth of the Canidæ in 1880, which has been supported by Scott and other palæontologists, and finally set forth with fresh arguments by Dr. Wortman; this 'premolar-analogy' theory is to the effect that the key to the past evolution of the molar teeth is to be found in the subsequent or present evolution of the premolar teeth, and that thus in many groups of animals at least the protocone occupies the same position in the upper molars as in the upper premolars. Fifthly, that all the known Upper Cretaceous mammals with triangular molars accord with the Upper Jurassic mammals in exhibiting the antero-internal cone as the main cone. Finally, that no such variations of structure are observed in the upper molars of the most primitive mammals as would be the case if there had been different modes of origin of the triangular or tritubercular crown.

In a succeeding article I shall take up and discuss some of the other points and theories raised in Dr. Wortman's interesting and important papers.

EXPLANATION OF PLATE XXI.

FIGURE 1.—Superior molars of *Dryolestes* Marsh. *A*. Series of the left side, external and crown views. *B*. Series of the right side, external, crown and internal views. Yale Museum.
pr, pr, pr, main internal cusps believed to be protocones.
?pa, ?me, smaller external cusps believed to be para- and metacones.
c, c, c, external and internal cingula.
i. o. f. infraorbital foramen.

FIGURE 2.—Superior molars of *Peralestes* Owen. Right side. External, oblique and crown views. British Museum.
mts, metastyle. Other abbreviations as in fig. 1.

FIGURE 3.—Superior molars of *Kurtodon* Osborn. Left side. British Museum.

* Collected Memoirs, vol. iv, p. 450.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Gases Occluded or Evolved by Radium Bromide.*—Dewar and Curie describe some experiments made with $0{\cdot}4^g$ of radium bromide. The pure, dry salt was placed in a glass tube communicating with a small Geissler tube and a mercury manometer, and a very perfect vacuum was produced in the apparatus. During three months gas was given off at the rate of 1^{cc} per month, and an examination of the spectrum by means of the Geissler tube showed only the presence of hydrogen and the vapor of mercury. It is possible that a minute quantity of moisture was introduced with the salt, and that this was gradually decomposed under the influence of radium.

The sample of radium bromide was then taken to England in order to make other experiments with it, and there it was transferred to a vessel of fused quartz, where it was heated to fusion at a red heat after the air had been exhausted by means of a mercury pump. The gases given off in this operation were passed through three U-tubes cooled with liquid air, which retained the greater part of the radium emanation and the less volatile gases. The more volatile gases collected in this way amounted to $2{\cdot}6^{cc}$; they had carried with them some of the emanation and were radio-active and luminous. Dewar examined the spectrum of this spontaneous light by means of a photographic spectroscope with a quartz prism and an exposure of three days, with the result that three bands belonging to nitrogen were obtained. When the gas was subjected to the electric discharge in a Geissler tube, the spectroscopic bands of nitrogen were also obtained, and upon condensing the nitrogen by exposure to the temperature of liquid hydrogen a high vacuum was produced in the Geissler tube, and the spark then indicated the presence of nitrogen, but nothing else.

The quartz tube containing the radium bromide which had been fused and thus freed from occluded gases was then sealed while exhausted, by means of the oxyhydrogen blowpipe, and taken back to Paris. Then, twenty days after it had been sealed, Deslandres illuminated the interior of the tube by a Ruhmkorff coil by the aid of small coatings of tin-foil applied to the exterior of the ends of the tube, and obtained the complete spectrum of helium, with no other lines, by means of a photographic spectroscope with a quartz prism. This result agrees with those of Ramsay upon the production of helium by radium salts dissolved in water, and it is interesting in showing that the presence of water is apparently unnecessary for this production of helium.—*Comptes Rendus*, cxxxviii, 910. H. L. W.

2. *Uranyl Double Salts.*—Rimbach, Bürger and Grewe have prepared a large number of these double salts, many of which

are new, and have studied their solubility in and decomposition by water. It was found that a large number of double chlorides, bromides, and sulphates correspond to the type $UO_2X_2'\cdot 2XX'$, while the double nitrates, chromates, and fatty-acid salts belong to the type $UO_2X_2'\cdot XX'$, where X signifies an atom of a univalent metal, and X′ a valency of a negative atom or radical. There are also exceptional types, such as $UO_2X_2'\cdot 4XX'$.

The stability of the double salts with water was found by analyzing saturated solutions of them prepared at different temperatures. When the ratios of the constituents in solution did not agree with the composition of the original compound, decomposition by water was shown. It was found that all the double nitrates are thus decomposed at the lower temperatures experimented with, while the double chlorides are more stable, and those containing alkali-metals of higher atomic weights (Rb and Cs), or complex radicals of strongly basic character, are not decomposed at the observed temperatures. The alkali-metal double sulphates are also stable, except when they form salts of the type $UO_2X_2'\cdot 4XX'$, which are extensively decomposed by water. All of the salts decomposed by water were found to become stable at higher temperatures, usually at about 60 or 80°. —*Berichte*, xxxvii, 461. H. L. W.

3. *The Presence of Formic Aldehyde in the Atmospheric Air.* —In the course of researches upon the atmospheric air, H. Henriet has detected the existence in it of a gaseous substance, other than formic acid, possessing energetic reducing action, and capable of reducing Fehling's solution and of decolorizing iodide of starch. In order to study this compound and to determine its identity, he examined rain-water which came from fogs. The samples of water, after filtration, were concentrated slowly upon the water bath from a volume of 30 or 40[l] to about 200[cc]. The samples were neutral at first, but became acid upon concentration, and deposited a certain quantity of calcium sulphate which was removed by filtration. The products which were strongly colored, with an orange-yellow tint, were subjected to simple distillation, and the distillates contained formic acid and a reducing agent which distilled in the presence of acids or alkalies, and gave the general reactions for aldehydes as well as special reactions for formic aldehyde.

The author concludes that formic aldehyde exists in the air, and that this substance, which is a powerful antiseptic, plays an important rôle in connection with the purity of the air.— *Comptes Rendus*, cxxxviii, 203. H. L. W.

4. *Revision of the Atomic Weight of Iron.* — About four years ago Richards and Baxter, by the reduction of ferric oxide by hydrogen, obtained the value 55·883 (O = 16·000) for the atomic weight under consideration. Baxter has recently made further determinations of this atomic weight by comparison of carefully purified and sublimed ferrous bromide with the silver bromide produced by it, or, in other cases, the silver required to

react with it. The average result, after all corrections had been made, was 55·870, a remarkably close agreement with the result of the other method.

In connection with this work the effect of the earth's magnetism upon the weight of magnetic substances has been discussed, and it has been shown by experiment to be entirely inappreciable.—*Zeitschr. Anorgan. Chem.*, xxxviii, 232. H. L. W.

5. *Method of Separating Iron and Aluminium.*—A method for making this analytical separation by boiling in the presence of an excess of sodium thiosulphate has been suggested by Chancel, but it has not been found satisfactory. LECLÈRE has modified the method by first adding ammonium thiosulphate to the very dilute solution containing a slight excess of sulphuric acid. This reduces the iron to the ferrous condition. Then a large excess of ammonium formate is added, and the aluminium is precipitated by boiling, in the state of basic formate. In drying the precipitate it is advisable to treat it with nitric acid, in order to destroy formic acid and prevent the presence of a residue of carbon in the ignited alumina. The iron can be precipitated in the filtrate as sulphide.—*Comptes Rendus*, cxxxviii, 146. H. L. W.

6. *Phosphorescence.*—ALBERT DAHMS gives an historical summary of the results of Seebeck and of Becquerel; and takes up the study of the phenomena discovered by them with the additional aid of photography. A number of interesting photographs accompany the paper. The various substances were exposed to the light of the carbons of an electric arc, and the photographs show carbon bands in the blue portion of the spectrum, and also in some cases bands in the extreme infra-red. The author shows that the phenomena are conditioned not only by the relative velocities of the rays, but also by the amount of energy contributed to the phosphorescent substances, and also by the inherent energy of such substances.—*Ann. der Physik*, No. 3, 1904, pp. 425–463. J. T.

7. *Preliminary Measurements of the Short Wave Lengths discovered by Schumann.*—For the past few years Dr. Theodore Lyman has been engaged in the Jefferson Physical Laboratory in an attempt to measure the short wave lengths discovered by Dr. Victor Schumann; but it is only recently that this attempt has proved successful.

Working in an atmosphere of hydrogen with a concave grating ruled upon speculum metal, an end-on tube filled with hydrogen gives numerous lines below the aluminum group at 1854. The shortest wave length so far observed has a value 1178 Ångström units. The limit of error is two units.

It is interesting to note that, contrary to expectation, speculum metal is able to reflect these very short wave lengths to a considerable degree. This is merely a preliminary notice. The author has in preparation a complete list of these new wave lengths; and he has good hopes of still further extending the spectrum. It is

his purpose to publish a detailed account of the investigation in the Proceedings of the American Academy and perhaps elsewhere.

J. T.

8. *Heating effect of the Radium Emanation.* — It has been shown that the radiation emitted from a radium compound in a state of radio-active equilibrium may be divided into three parts:

(1) A non separable radiation consisting entirely of α rays; and constituting about 25 per cent of the total radiation.

(2) The radiation from the emanation occluded in the radium, also consisting entirely of α rays.

(3) The excited radiation produced in the mass of the radium, consisting of α, β, and γ rays.

(2) and (3) together constitute about 75 per cent of the total radiation.

It is found that the emanation supplies 18 per cent, the non-separable activity 25 per cent, and the excited activity 57 per cent of the total activity of radium. On heating or dissolving a radium compound in an open vessel, the emanation is released and can be entirely removed by a current of air. The excited activity, or emanation X, is non-volatile, and being left in the radium immediately begins to decay. Since fresh emanation is being constantly produced by the radium and occluded in it, the activity of the radium after falling to a minimum gradually rises again, and in the course of a month nearly reaches its original constant value. Interesting curves are given of the energy of the various forms of activity; and calculations of the amount of heat from the emanation. It is computed that the amount of heat liberated per hour from 1^{cc} of the emanation lies between $1{\cdot}25\times10^{5}$ and $1{\cdot}25\times10^{6}$ gram-calories. This amount of heat would probably be sufficient to raise to a red heat, if not to melt down, the glass tube containing it. One pound weight of the emanation would initially radiate energy at the rate of 10^{4} to 10^{5} horse-power, and while the heating continued would emit an amount of energy between 6×10^{4} and 6×10^{5} horse power days. According to the author's disintegration hypothesis, this energy is derived from the energy latent in the radium atoms and is released in the various stages of their disintegration. — *Rutherford and Barnes in Phil. Mag.*, Feb., 1904, pp. 202–219.

J. T.

9. *Nature of the Emanations from Radium.*—Lord Kelvin finds it difficult to believe in the atomic disintegration hypothesis of Rutherford, and suggests that radium may transform etheric vibrations into its peculiar manifestations of energy, just as a black cloth in a test tube filled with water shows an increase of heat over a similar receptacle filled with water and containing a piece of white cloth.—*Phil. Mag.*, Feb., 1904, pp. 220–222.

J. T.

II. Geology and Natural History.

1. *United States Geological Survey.* — The following folios have recently been published:

No. 97. Parker folio, South Dakota; by J. E. Todd.

No. 99. Mitchell folio, South Dakota; by J. E. Todd.

No. 100. Alexandria Folio, South Dakota; by J. E. Todd and C. M. Hall.

Four connecting folios dealing with the James River region have thus far been published and they show clearly the unity of this geologic province. Sioux quartzite (Algonkian) underlies the region and constitutes the "bed rock" of the well drillers. The Paleozoic, Triassic and Jurassic are absent, and the Cretaceous is represented by the Colorado Group (Benton and Niobrara). Rock outcrops are exceedingly rare and the distribution and characters of the pre-glacial formations is determined in large measure from the numerous artesian well records.

The whole area is practically a plain of till diversified by a series of moraines left by the retreating glacial lobe. The till is from 10 to 350 ft. deep and appears to belong entirely to the Wisconsin epoch. No complicated drainage modifications are apparent, and, in fact, the area exhibits simple geologic structure in every respect. These three folios together with the Olivet (No. 96), are particularly valuable for their descriptions of glaciation and artesian water conditions.

No. 98. Tishomingo folio, Indian Territory; by Joseph A. Taff. The Tishomingo quadrangle exhibits two types of topography; a Cretaceous peneplain composed of Paleozoic formations, and a dissected plain of Cretaceous strata. In addition to the Cretaceous, Cambrian, Silurian, Devonian, and Carboniferous strata are represented. A pre-Cambrian granite occupies a considerable area and with it are associated a quartz-monzonite and numerous dikes of diabase, diorite and aplite intruded at different times. A commendable feature of the folio is the publication of lists of fossils with each formation and the attention given to correlation. The Arbuckle uplift, occupying the northern half of the quadrangle, is composed of a number of folds, constituting a broad arch. The synclines are faulted to an extraordinary degree, the main faults being approximately parallel with the folds. "The folds are open and never overturned" . . . "and the faulting, in most cases at least, is of the normal type or drop faulting." Asphaltic deposits of economic importance occur in the Ordovician sandstone and limestone, and to less extent in the Carboniferous limestone conglomerate.

2. *Glacial Geology of Tasmania;* by J. Walter Gregory. Quart. Jour. Geol. Soc., lx, 37.—The existence of Carboniferous glacial beds in Tasmania has long been known, and in 1894 E. J. Dunn furnished the first conclusive evidence of Pleistocene glacial action, after an examination of the summits of the Western Highlands. Prof. Gregory now shows that, contrary to the view

held by most observers of that region, there has been widespread glaciation in Tasmania down at least to the 400 ft. level. These low level deposits are best preserved in the valleys of the King, the Linda and the Pieman River.

3. *Report on a Geological Reconnoissance of the Iron Region of Angat, Bulacan;* by H. D. McCaskey. 62 pp., 56 pls. Bull. 3, Mining Bureau Phillippine Islands.—A sketch of the Geology of the Province of Bulacan shows many interesting features. The rocks described are pre-Tertiary crystallines (diorites?), modern volcanics, Tertiary or early Quaternary sedimentary rocks, tuff deposits, alluvium. One fossil found is of early Mesozoic or late Paleozoic age. The photographs, tables of analyses and maps are valuable additions to the text.

4. *Mineral Tables for the Determination of Minerals by their Physical Properties*; by Arthur S. Eakle. Pp. 73. New York, 1904 (John Wiley & Sons).—Mineral tables, based upon physical properties, have the advantage as compared with those which are strictly chemical, that they call the attention of the student to the visible characters of the specimens he is handling, and hence tend to increase his knowledge of them. The Weisbach tables have been long and favorably known, but this volume now issued differs from them, in that the fundamental basis of classification is that of *color*. The arrangement is based, first, on the color of the fine powder, the *streak*, and second upon the color of the mass. The individual species, with their other characters given in tabular form, are arranged by their specific gravities. The tables have evidently been carefully prepared, and under the guidance of a good teacher should give excellent results.

5. *Meteorite Catalogues.* — The catalogue of the Collection of Meteorites of the Field Columbian Museum in Chicago, compiled by Dr. O. C. Farrington, has recently been issued. It shows that the collection has grown from the 179 falls in July 15, 1895, to 251 falls in May 1, 1903, and the total weight from 2,099 to 2,289 kilograms. The collection has large masses of the following: Brenham 445 kgs., Canyon Diablo 690 kgs., Long Island 528 kgs., Toluca 177 kgs.

A catalogue of the collection of the Berlin University, by Prof. C. Klein, has also appeared. This collection is now one of the largest in the world in number of falls, the total number amounting to 450. The latest estimate (quoted by Klein) for the Vienna collection gives 560 localities in 1903, for London 476 in 1896, for Paris 466 in 1898. In addition to the classified list of meteorites, this catalogue also contains more or less detailed descriptions of several meteorites. A point of unusual interest is the identification of the mineral *leucite* which is present in minute trapezohedrons in the Schafstädt meteorite (1861) with anorthite, augite, etc.; it is probably also present in the Pawlowka (1882) meteorite.

6. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes;* edited by J. Stanley Gardiner. Vol. II, Part

II, pp. 589–698, with text figures and 12 pls. (See this Journal, xiii, 321; xiv, 74; xv, 240, 488; xvi, 400.)—Mr. E. A. Smith, in his report on the "Marine Mollusca" of the expedition, mentions that this collection is of special interest, as being the first of any importance ever studied, from this region. Among the 380 species found, probably all of the more conspicuous forms which actually occur there are represented, only the more obscure or smaller ones having been overlooked. Although the fauna is similar to that of the islands of the Indian Ocean, it is curious that the larger proportion of the species have been previously noted from the China Seas eastward and in the Pacific. Many common widely distributed species are represented, although certain genera which occur in the surrounding seas do not appear. About three-quarters of the species are known to exist in the seas surrounding the Philippine Islands and Malay Archipelago and farther north; about one-quarter are similar to those from Japan. Twenty-two species are described as new, most of which are well figured.

Mr. R. A. Punnett reports the collection of "Enteropneusta," in numbers and variety of forms, to be the most extensive ever made. Seven species and one genus (*Willeyia*) are described as new and the genus *Ptychodera* is for the first time thoroughly studied.

Mr. L. A. Borradaile continues his extensive studies of the "Marine Crustaceans;" his report on the "The Spider-crabs (*Oxyrhyncha*)" being his tenth contribution. Of the twenty-nine species recorded, three are described as new. "The Classification and Genealogy of the Reptant Decapods" is also given.

K. J. B.

7. *North American Fauna, No. 23, Index Generum Mammalium:* A list of the genera and Families of Mammals by T. S. Palmer, Assistant Biological Survey. Prepared under the direction of Dr. C. Hart Merriam, Chief of Division of Biological Survey. Pp. 984. Washington, 1904.—Of the three parts of which this comprehensive work consists, part 1 (pp. 7–718), giving an annotated list of the generic names of mammals, was begun in 1884 by Dr. Merriam and completed by Dr. Palmer. Parts 2 and 3 have been prepared by Dr. Palmer alone; they give (2) an alphabetical list of families of mammals (pp. 719–776) and (3) a classified list of the generic names arranged by orders and families (pp. 777–984).

III. Miscellaneous Scientific Intelligence.

1. *Christian Faith in an Age of Science;* by William North Rice. Pp. 425, New York, 1903 (A. C. Armstrong & Son).—The question to which an answer is offered in this most interesting volume is, "Can the faith which first breathed in the unscientific atmosphere of the first century survive in the scientific atmosphere of the twentieth century?"

The great value of the book lies in the fact that the author combines in his own personality the highest training, knowledge and practical comprehension of modern science with a profound and reverent Christian faith.

In the first part a general survey of the progress of human knowledge is presented, precise and exact in its criticism. It is shown how step by step the crude fancies of a timid, ignorant and superstitious people have been replaced by the exact and demonstrated facts and laws of science:—a flat world, with the mountain pillars supporting the roof of heaven, has become a globe whirling free in space; geocentric astronomy, the seven days of creation, miracles, spontaneous generation and a carpenter idea of, and an interfering God, have become the heliocentric solar system, the illimitable spaces of the universe, the millions of years of geologic time, the orderly evolution of worlds, of the structure of the earth and of organisms, the conservation of energy and the unerring sequence of cause and effect. These advances of knowledge have seemed to take away the very foundation upon which the old systems of theology rest.

In the second part, with the same calm, scientific method, the author shows how religious ideas have become clarified and their essential truths brought out more distinctly, as the world has advanced. We find in his terse, but sufficiently full, portrayal of the modern conceptions of the personality of man and of God, the scientific conception of providence, of prayer and the nature and meaning of the bible, an admirable and sufficient answer to his original question.

The conclusion reached is that, although, as in science "certainty in natural science is demonstrated to be absolutely unattainable;" so "no claim of certainty can be maintained in regard to Christianity as a system or in regard to any particular doctrine of Christianity." Nevertheless, it is a fact, that, "The generation in which we live—the generation which has accepted the doctrines of modern science—is more strongly influenced by the teachings of Christianity than any previous generation, and multitudes of men and women find that the acceptance of scientific teachings in no wise disturbs their personal religious life," and "our partial knowledge justifies the prophetic hope that no scientific discovery will contradict the essence of Christianity, and that the end of all questioning will be the reëstablishment of faith." H. S. W.

2. *Beiträge zur chemischen Physiologie;* herausgegeben von F. Hofmeister. IV. Band, 9–12; Braunschweig, 1903 (Vieweg u. Sohn).—The closing parts of this volume contain a number of important papers among the fifteen contributions. These include extensive studies on the occurrence of albumoses in the blood, by O. Schumm; two papers on glycolytic ferments; an elaborate investigation of the antecedents of the fibrin ferment, by Morawitz; and several contributions pertaining to the chemistry of the proteids. The possibility of transforming albumins into globulins is emphasized in detail by L. Moll; and Embden and v. Fürth have demonstrated that the rapid disappearance of typ-

ical effects after suprarenin (adrenalin) injections is not due to any rapid oxidation of this compound in the body, but rather to its gradual dilution by diffusion and distribution in the organism.

L. B. M.

3. *Astronomical Observatory of Harvard College*, Edward C. Pickering, Director.—Recent publications are the following:

Annals, Vol. XLIII, part iii. Observations and Investigations made at the Blue Hill Meteorological Observatory in the years 1901, 1902, under the direction of A. Lawrence Rotch; with appendices containing a discussion of the effect of meteorological conditions upon audibility; also the observations with kites, 1897–1902, and a description of the kites and instruments. Pp. 115–239, with four plates.

Annals, Vol. XLVIII, No. ix, Geographical Position of the Arequipa Station, by Winslow Upton, pp. 221–273.

Circular, No. 74. Variable Stars of long Period, pp. 10. No. 75, Variability of Iris (7).

4. *Publications of the United States Naval Observatory*, Rear-Admiral Colby M. Chester, U. S. N., Superintendent. Second Series, Volume V. *Meteorological Observations and Results, 1893–1902.* Pp. x, 443, 4to. Washington, 1903.—This volume contains the usual meteorological observations, given in tabular form, of barometric pressure, temperature, wind direction and velocity, etc., taken at the Naval Observatory, Georgetown Heights, during the decade from 1893 to 1902.

5. *Where did Life Begin?* by G. Hilton Scribner. 75 pp. New York, 1903. (Charles Scribners' Sons.)—In 1883 Mr. Scribner published a monograph advocating the theory that living forms originated within the circumpolar area. This book is now republished, and it is worthy of note that the "Scribnerian theory of the Place of the Origin of Life" is in accord with the conclusions reached by Dr. J. L. Wortman from a study of vertebrate fossils and by Dr. Wieland from a study of fossil plants (this Journal, xv, 419; xvi, 401).

6. *Field Columbian Museum.* — Among the recent publications is to be mentioned Vol. IV of the Anthropological Series by George A. Dorsey (pp. xii, 228, with 139 plates), giving a minute and fully illustrated description of the famous Arapaho Sun Dance. Other publications are the following: On the Osteology of *Nyctosaurus* (Nyctodactylus) with notes on American Pterosaurs by S. W. Williston. Structure and Relationship of Opisthocœlian Dinosaurs, Part 1, *Apatosaurus* Marsh; by E. S. Riggs. Catalogue of Meteorites by O. C. Farrington, mentioned on p. 329.

7. *Bureau of American Ethnology: Twentieth Annual Report to the Secretary of the Smithsonian Institution, 1898–99;* by J. W. Powell, Director. Washington, 1903.—This volume contains the report of the Director (pp. i–ccxxiv) and also an interesting paper by W. H. Holmes (pp. 1–237) giving a description of the aboriginal pottery of the eastern United States, illustrated by a hundred and seventy-seven plates and seventy-nine text figures.